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P.O. Box 527
Ottawa, Ontario
K1P 5V6

C.P. 527
Ottawa (Ontario)
K1P 5V6

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DISCUSSION PAPER NO. 176

Preliminary Report: Innovation and Technological Change in Five Canadian Industries

by Dennis P. DeMelto
Kathryn E. McMullen
Russel M. Willis

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INNOVATION AND TECHNOLOGICAL CHANGE IN FIVE CANADIAN INDUSTRIES

Telecommunications Equipment and Components
Electrical Industrial Equipment
Plastics Compounds and Synthetic Resins
Non-ferrous Smelting and Refining
Crude Petroleum Exploration and Production

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Résumé

Le présent rapport porte sur l'analyse des processus d'innovation et d'évolution technologique dans cinq industries canadiennes, soit le matériel et les pièces détachées de télécommunications, le matériel et les appareils électroniques industriels, les matières plastiques et les résines synthétiques, la fonte et l'affinage de métaux non-ferreux, ainsi que la prospection et la production de pétrole brut. Le but premier du rapport consiste à présenter des données de base sur la nature et les caractéristiques du changement dans les entreprises et industries canadiennes ayant participé à l'enquête sur les principales innovations adoptées par elles entre 1960 et 1979. Nous étions d'avis que les données factuelles et détaillées sur ce sujet de première importance étaient trop rares. Un deuxième but de l'étude était d'isoler et d'analyser les différences du point de vue des innovations et de l'évolution technologique entre des entreprises et industries de caractère différent. Nous avons découvert des variations très marquées quant au processus de changement technologique, par exemple, entre les petites et les grandes entreprises, et entre les entreprises canadiennes sous contrôle étranger et les entreprises canadiennes sous contrôle canadien. Le présent résumé donne surtout un aperçu général des résultats de notre analyse, s'arrêtant peu aux variations entre industries. Nous espérons que ces données contribueront largement à nous faire mieux comprendre les facteurs qui influencent le plus le processus d'innovation et l'évolution technologique dans les industries canadiennes, et à faire élaborer des politiques industrielles plus efficaces.

Principales caractéristiques des innovations canadiennes

Nous avons procédé à l'examen de 283 innovations importantes, dont 82 s'appliquaient à des procédés, et 201, à des produits. Des cinq industries étudiées, deux étaient orientées vers les produits, et deux vers le traitement.

Les innovations consistant en la création de produits et de procédés nouveaux représentent 60 % de l'ensemble. Il ne fait aucun doute que les entreprises considèrent également l'amélioration des produits et procédés comme jouant un grand rôle dans le processus d'innovation au Canada, puisque 40 % des innovations d'importance dont on nous a fait rapport sont ce qu'on appelle des innovations d'amélioration.

En outre, l'imitation est aussi considérée comme un moyen important de mettre au point des produits et procédés nouveaux ou améliorés dans l'industrie canadienne. Un peu moins de la moitié des innovations signalées concernaient des imitations de nouveautés introduites ailleurs dans le monde, alors qu'un peu plus de la moitié correspondaient à des idées

originales, "des premières mondiales pour le Canada". Les entreprises sous contrôle étranger ont copié plus souvent les grandes innovations produites ailleurs, alors que les entreprises de propriété canadienne ont produit plus souvent des innovations à partir de concepts originaux.

Les innovations de procédés ont davantage été le fruit de l'imitation que ne l'ont été les produits. La plupart des changements effectués par imitation dans les entreprises canadiennes se sont inspirés d'innovations introduites d'abord aux États-Unis.

Quand nous qualifions les innovations d'originales ou d'imitatives, nous n'entendons pas qu'une catégorie est supérieure à l'autre. Il se peut fort bien qu'une "imitation" soit plus importante du point de vue de ses répercussions sur la productivité, la compétitivité et la rentabilité d'une entreprise au Canada qu'une innovation "originale". Il se peut même qu'une imitation constitue une nette amélioration sur une "première mondiale".

Plus de la moitié des innovations imitatives se sont fondées sur des technologies développées sur place, au Canada, dans l'entreprise répondante. Par contre, 22 % des innovations originales ont été inspirées, en tout ou en partie, par des technologies importées.

L'innovation exige énormément de temps. Les entreprises ont mis, en moyenne, deux ans et demie à mettre au point un procédé et un an et trois quarts à créer un produit.

De façon générale, les entreprises ont décidé d'introduire des innovations lorsqu'elles supposaient un court délai de recouvrement des coûts. Pour plus de la moitié des produits et des procédés adoptés, les sommes dépensées pour leur mise au point pouvaient être récupérées en moins de trois ans.

<u>Ressources nécessaires à l'innovation, par étape du processus de changement technologique</u>

Le processus de l'évolution technologique est défini selon trois étapes : l'invention, l'innovation et la diffusion. Le présent rapport porte surtout sur les activités des entreprises au cours des deux premières étapes. A des fins d'analyse, les activités innovatrices des entreprises ont été divisées en cinq éléments : la recherche de base, la recherche appliquée, la mise au point ou le développement, la fabrication et la commercialisation.

S'il est vrai que les innovations sont onéreuses, ce sont celles qui concernent les procédés qui le sont le plus. En moyenne, les dépenses affectées aux innovations de procédés ont atteint 533 000 dollars comparativement à 213 000 dollars dans le cas des produits.

En général, ce sont les dépenses aux titres de la mise au point ainsi que de la fabrication qui constituent les principales composantes des coûts des innovations signalées, les coûts étant plus élevés pour le développement dans le cas des produits, et pour la fabrication dans le cas des procédés. En outre, plus le coût global de l'innovation est élevé, plus la proportion des coûts de la fabrication est haute et plus le pourcentage des coûts de la recherche et du développement est bas. La plupart des innovations signalées n'ont exigé aucune recherche de base, et une grande proportion d'entre elles, aucune recherche appliquée. Ces profils des coûts varient considérablement d'une industrie à l'autre.

Les profils moyens des dépenses au titre d'innovations fondées sur une technologie provenant d'une source extérieure à l'entreprise (par opposition à celles qui découlent d'une technologie mise au point par un travail interne) affichent des coûts de recherche de base très peu élevés, des coûts de recherche appliquée moins élevés et des coûts de développement seulement légèrement moins élevés, ce qui reflète le fait que lorsque les entreprises importent des techniques, elles bénéficient de recherches entreprises à l'extérieur, habituellement à l'étranger. Il n'est pas sûr que ces recherches auraient pu être effectuées au Canada, ou que de fait elles l'auraient été en l'absence de cette importation de technologie.

Le ratio de la recherche et du développement par rapport aux ventes a tendance à baisser systématiquement à mesure qu'augmente la taille de l'entreprise (selon le nombre d'employés). Les entreprises sous contrôle étranger, de toutes tailles, ont des ratios R et D-ventes moins élevés que leurs homologues sous contrôle canadien, ce qui traduit le fait qu'elles sont plus actives dans l'importation des technologies, étant donné qu'elles ont accès aux résultats de la recherche et du développement de leur société-mère et de ses filiales étrangères et n'ont pas intérêt à refaire ce travail au Canada.

Les ratios R et D-ventes varient considérablement entre les industries, s'établissant à une moyenne de 9,6 % pour le matériel et les pièces détachées de télécommunications, de 3,2 % pour le matériel et les appareils électriques industriels, de 2,3 % dans l'industrie de la production de pétrole brut, de 1,3 % dans les matières plastiques et les résines synthétiques et de 1,3 % dans la fonte et l'affinage.

Sources technologiques des innovations canadiennes

La plupart (66 %) des innovations signalées à l'occasion de l'enquête se sont appuyées sur une technologie mise au point à l'intérieur de l'entreprise. Un autre 7 % se sont fondées sur des technologies dont certaines avaient été mises au point dans l'entreprise, et d'autres ont été prises de l'extérieur. Les 27 % restants découlaient principalement de techniques provenant de sources extérieures à l'entreprise innovatrice. Dans l'ensemble, il ne paraît pas y avoir dépendance excessive sur les technologies importées.

Nous avons constaté une nette tendance chez les entreprises à mettre au point elles-mêmes les techniques nécessaires aux innovations relatives aux produits et, au contraire, à acquérir de sources extérieures la technologie nécessaire aux innovations visant les procédés.

Les entreprises sous contrôle canadien ont recouru plus souvent, pour leurs innovations, aux techniques qu'elles ont elles-mêmes développées (82 %). Néanmoins, plus de la moitié des innovations introduites dans les entreprises sous contrôle étranger (54 %) se sont également fondées sur une technologie mise au point sur place.

Les entreprises sous contrôle canadien ont utilisé des techniques importées (en tout ou en partie) pour 12 % de leurs innovations dans le domaine des produits et pour 40 % de leurs innovations touchant les procédés. Dans le cas des entreprises de propriété étrangère, les chiffres sont de 39 % et de 58 % respectivement.

Les très petites et les très grandes entreprises sous contrôle étranger sont celles qui ont le plus puisé aux sources externes de technologie, utilisant ce genre de techniques pour 65 et 45 % respectivement de leurs innovations. Les entreprises de toutes tailles de propriété canadienne, et les entreprises moyennes sous contrôle étranger se sont assez rarement servies et la technologie importée pour leurs innovations importantes.

La majorité des sources extérieures de la technologie utilisées par les établissements répondants sont étrangères, et plus précisément américaines. Seulement 15 % de tous les transferts de technologie, au Canada, se sont faits sur le plan interne, et la plupart de ceux-ci, par l'intermédiaire de consultants.

Des 96 transferts de technologie, 55 % ont été effectués entre sociétés d'une même multinationale; les autres 45 % se sont faits entre des entreprises sans lien de dépendance. Il ne s'est produit que 43 transferts de ce dernier genre, mettant en cause des clients, des fournisseurs, des entreprises à risques partagés et des consultants.

Les entreprises sous contrôle étranger comptent beaucoup sur les sociétés mères et les filiales pour l'importation de technologies; en effet, 70 % de leurs importations sont venues d'entreprises affiliées à la même multinationale. Le fait que 30 % de leurs transferts de technologie aient été de sources sans lien de dépendance mérite d'être souligné. Quant aux entreprises de propriété canadienne, tous les transferts, sauf un, sont venus de sources sans lien de dépendance.

Les ententes portant sur le transfert de technologies à l'intérieur d'une même multinationale contiennent souvent des dispositions accordant à la filiale l'accès aux développements futurs de la technologie au sein de la société. L'ensemble des techniques ainsi transférées est ordinairement complet, fournissant tout un évential de droits sur la fabrication et la marque de commerce. En outre, ces ententes sont, dans bien des cas, verbales.

Le traitement accordé aux entreprises sous contrôle étranger dans le cas d'un transfert d'une source sans lien de dépendance a été considérablement différent de celui qu'on trouve dans le cas d'un transfert intra-société. Comparativement aux transferts de sources sans lien de dépendance aux entreprises sous contrôle canadien, les transferts de ce genre aux entreprises étrangères ont été moins complets, mais ils ont eu tendance à se faire plus souvent de façon continue que ce n'est le cas pour les sociétés canadiennes. Dans l'ensemble, les transferts de sources sans lien de dépendance constituent un ensemble moins complet de techniques que les transferts intra-société.

Les renseignements que nous avons obtenus sur les retards -- c'est-à-dire sur le temps écoulé entre le lancement d'un produit ou la première utilisation d'un procédé dans le monde, et le lancement ou la première utilisation par l'entreprise répondante -- sont assez compliqués. Pour les innovations de produits, et en ce qui concerne les procédés dans les entreprises de propriété canadienne, le temps écoulé avant leur introduction au Canada a été plus court dans les cas où elles ont été mises au point par le recours à des technologies importées. Par contre, dans le cas des innovations touchant les procédés dans les entreprises sous contrôle étranger, les retards ont été moins longs dans les cas où la technologie a été développée sur un plan interne. Quelle que soit la source de la technologie, les entreprises de propriété étrangère ont imité plus rapidement les procédés innovateurs que les entreprises canadiennes, quoique cela ne tienne pas dans le cas des produits.

L'évolution technologique dans les entreprises de propriété canadienne et étrangère

Les entreprises sous contrôle canadien représentent 48 % de toutes les entreprises répondantes; le reste, soit 52 % sont de propriété étrangère, et pour une large part, américaine.

En moyenne, les entreprises sous contrôle étranger sont beaucoup plus importantes que leurs homologues canadiens, tant pour la taille que pour le nombre d'employés.

Les entreprises étrangères ont effectué 70 % de toutes les innovations dans les procédés, ce qui reflète, en partie, le rôle prédominant qu'elles jouent dans les industries de traitement. En outre, elles ont produit un peu plus d'innovations consistant en procédés nouveaux que les entreprises canadiennes. Par contre, ces dernières gagnaient sur le plan des nouveaux produits. De l'ensemble des innovations dans les produits, 52 % ont été l'oeuvre des entreprises de propriété étrangère.

Les entreprises sous contrôle étranger consacrent plus de temps au développement d'innovations, tant pour les procédés que pour les produits, la différence étant plus marquée pour les premiers. De façon générale, ces entreprises adoptent aussi plus rapidement les innovations en ce qui concerne les procédés déjà mis en oeuvre à l'étranger.

Les dépenses au titre de la recherche et du développement ont été moins élevées chez les entreprises de propriété étrangère que chez les entreprises sous contrôle canadien, notamment en raison du fait que la part de leurs dépenses au titre de la recherche sont moins élevées, surtout dans le cas des innovations dans les procédés. Ces différences reflètent avant tout l'importance des innovations dans les entreprises sous contrôle étranger et leur tendance plus marquée à importer des technologies. Les faibles dépenses au titre de la recherche en vue d'innovations inspirées de technologies importées sont imputables à l'accès qu'ont ces entreprises aux résultats de la recherche et du développement entrepris par la société mère et ses filiales.

Même dans les cas où les innovations se sont appuyées sur des technologies étrangères, elles ont nécessité beaucoup de recherche et de développement, sauf pour celles qui visaient les procédés dans les entreprises sous contrôle étranger pour qui, dans bien des cas, presque toutes les dépenses se font à l'étape de la fabrication.

En termes absolus, les dépenses moyennes affectées aux innovations par les entreprises sous contrôle étranger ont été considérablement plus élevées que celles des entreprises canadiennes, tant par rapport aux dépenses totales que par rapport à celles de chaque étape du processus d'innovation.

Le temps requis pour le recouvrement des sommes versées pour les innovations par les entreprises de propriété étrangère a été plus long que celui des entreprises canadiennes.

Les innovations touchant les produits mis au point par les entreprises étrangères ont généralement obtenu une valeur marchande plus élevée que celles des entreprises sous contrôle canadien, cette valeur étant plus grande même pour chaque dollar de dépenses à cet effet.

En 1978, 68 % des innovations dans les produits des entreprises sous contrôle canadien ont été exportées, comparativement à 57 % dans le cas des entreprises de propriété étrangère. Cette différence entre les deux genres d'entreprises provient du fait que les innovations visant les produits, lorsqu'elles proviennent de technologies importées, s'exportent très peu. Cependant, lorsqu'elles font l'objet d'exportation, la valeur moyenne des innovations de produits développées par les entreprises sous contrôle étranger est supérieure à celle des innovations mises au point par les entreprises de propriété canadienne.

Le progrès technologique dans les petites et grandes entreprises

La plupart des entreprises comprises dans l'échantillon (52 %) sont de petite taille, puisqu'elles emploient 100 personnes ou moins; 15 % seulement des entreprises répondantes emploient plus de 500 personnes.

Dans l'ensemble, les petites entreprises s'intéressent principalement aux innovations relatives aux produits (79 % de leurs innovations sont des produits), alors que les grandes sociétés se concentrent dans une large mesure sur les innovations portant sur les procédés (les procédés représentent 54 % de leurs innovations). Il en va de même, de façon générale, au niveau de l'industrie.

De tous les types de sociétés, les petites entreprises canadiennes sont celles qui consacrent le plus d'efforts aux innovations liées à des produits; elles mettent plus de temps au développement et à la commercialisation de leurs produits que leurs homologues étrangers. Les grandes entreprises canadiennes sont également plus orientées vers l'innovation en matière de produits que leurs homologues étrangers. Ces entreprises consacrent effectivement plus de temps au développement et à la commercialisation de leurs innovations de produits que pour celles qui s'appliquent aux procédés. Cette caractéristique les distingue de tous les autres types d'entreprises.

Par ailleurs, les petites et les grandes entreprises sous contrôle étranger s'intéressent davantage aux innovations de procédés que leurs homologues canadiens.

Quelle que soit l'origine du contrôle de l'entreprise, les petites entreprises optent nettement pour des innovations dont elles peuvent recouvrer les coûts en moins de trois ans.

D'autre part, les grandes entreprises introduisent des innovations nécessitant un temps plus long pour le recouvrement des coûts.

Pour les petites entreprises, les coûts de développement constituent non seulement le plus important élément de leurs dépenses pour les innovations reliées aux produits, mais ils le sont aussi pour les innovations touchant les procédés. Pour les grandes entreprises, les coûts de développement représentent le plus important élément des dépenses affectées aux innovations relatives aux produits, alors que les coûts de mise en marché viennent au premier rang des dépenses engagées pour les innovations de procédés. En fait, dans le cas de ces entreprises, les dépenses de recherche pour les innovations de procédés ont tendance à représenter une plus forte proportion des dépenses globales que celles qui sont affectées au développement de ces mêmes innovations. L'importance des dépenses de recherche des grandes entreprises pour les innovations de procédés explique peut-être pourquoi elles consacrent plus de temps au développement.

Quelle que soit l'origine de leur contrôle, les grandes entreprises montrent une très grande propension à financer à 100 % leurs innovations à même leurs ressources. Les petites entreprises canadiennes et étrangères, ainsi que les entreprises étrangères de taille moyenne, ont également financé plus de 50 % de leurs innovations par leur propres moyens : toutefois, les entreprises canadiennes de taille moyenne ont eu davantage recours à des sources exterieures de financement.

Les petites et moyennes entreprises canadiennes ont fait appel à un grand nombre de sources extérieures, mais aucune d'entre elles n'a fourni une très grande proportion des fonds nécessaires au financement des innovations. Les entreprises étrangères de toutes tailles ont également recours à une variété de sources extérieures de financement, mais, celle à qui elles font appel le plus souvent leur assure une proportion appréciable des fonds requis pour l'innovation.

Le niveau de recherche et de développement dans les entreprises nationales est plus élevé que dans les entreprises sous contrôle étranger : en d'autres termes, les premières dépensent ordinairement davantage, selon le nombre d'employés, pour la recherche et le développement dans le domaine qui les intéresse. En outre, dans le cas des entreprises canadiennes, l'intensité de la recherche et du développement tend à diminuer à mesure que croît la taille de l'entreprise. Par contre, les entreprises étrangères ne montrent aucune tendance positive ou négative relativement à ce facteur.

Le mouvement de l'exportation des produits innovés est élevé pour toutes les tailles d'entreprises, mais il est encore plus fort dans les grandes entreprises. Dans le cas des entreprises exportatrices, les grandes entreprises ont exporté une plus forte proportion du total des ventes de produits innovés d'innovations que les petites. Il est donc manifeste que les considérations d'échelle jouent un rôle dans la capacité des entreprises à exporter.

Questions concernant la gestion et les effets des innovations

Dans leur décision d'innover, toutes les entreprises répondantes ont été fortement motivées par le désir de tirer parti des nouveaux moyens technologiques. Les facteurs liés au marché ont été également souvent cités. Les entreprises et industries orientées vers les innovations relatives aux produits, en particulier, les petites entreprises canadiennes, ont cherché à développer des produits répondant à des besoins du marché. Les grandes entreprises, de leur côté, concentraient davantage leurs efforts vers l'accroissement de leur part du marché. Les innovations de produits ont été également très influencées par les réactions des clients.

Les entreprises orientées vers l'innovation en matière de procédés, en particulier les entreprises étrangères et les grandes entreprises, se sont préoccupées plus que les autres types d'entreprises de réduire les besoins en énergie et en main-d'oeuvre quoique ces facteurs n'aient pas été souvent cités.

Le désir d'améliorer la qualité des produits couverts par l'innovation a été cité comme un important facteur de motivation dans la décision d'innover; il a été à l'origine d'environ 20 % des innovations des entreprises canadiennes et étrangères. Dans la décision d'innover, certains facteurs particuliers à telle ou telle industrie ont eu leur part à jouer. Par exemple, les deux industries qui ont été le plus affectées par la concurrence étrangère et intérieure -- celle des composés plastiques et des résines synthétiques, et celle de la fabrication de matériel et appareils électriques industriels -- ont également cité très souvent l'importance du désir d'améliorer la qualité des produits couverts par l'innovation.

Les sources d'idées et d'informations auxquelles puisent les entreprises pour le développement de leurs innovations montrent des différences prononcées selon les types d'entreprises. Les entreprises canadiennes comptent beaucoup sur leurs clients comme source d'idées pour leurs innovations de produits et sur leurs fournisseurs quant aux innovations couvrant les procédés. Par contre, les entreprises sous contrôle étranger se fient beaucoup aux sociétés mères et à leurs filiales pour ce qui est des idées et des informations sur les innovations de leurs produits et de procédés. Ces échanges intrasociété ont été particulièrement nombreux dans le cas des entreprises étrangères dont les innovations sont fondées sur une technologie venant de l'extérieur.

Il paraît donc évident que les sociétés mères constituent non seulement d'importantes sources externes de technologie, mais jouent également un rôle fondamental dans la génération d'idées et la solution de problèmes relatifs aux innovations de leurs filiales. Dans la plupart des cas, les entreprises canadiennes n'ont pas accès aux canaux de technologie appropriés que rendent possible les échanges intrasociété et doivent donc presque toujours traiter par des relations sans lien de dépendance. Les flux d'informations et de technologie émanant des échanges intrasociété sont facilités par la fréquence d'utilisation et l'intimité des interactions qui sont beaucoup plus élevées que dans les relations sans lien de dépendance.

Du point de vue des effets que les innovations rapportées ont exercé sur le nombre de travailleurs, il y a eu des augmentations nettes du nombre de travailleurs tant du côté de la production que des autres; les cas ou il n'y a eu que des variations du nombre d'employés sont négligeables. Ces effets ont été le plus prononcés dans le cas des innovations de produits et dans les petites entreprises.

En revanche, dans le cas des innovations relatives aux procédés, il importe de souligner qu'il y a eu des diminutions nettes du nombre de travailleurs employés; 20 % des innovations de procédés ont entraîné une diminution nette du nombre des travailleurs à la production. En outre, l'introduction de 11 % des innovations des grandes entreprises s'est traduite par une diminution nette du nombre de travailleurs à la production. Le nombre d'innovations donnant lieu à des diminutions nettes du nombre des travailleurs non affectés à la production a été peu élevé dans les deux cas.

Dans l'ensemble, ces résultats indiquent qu'il est très improbable que les principales innovations introduites durant la période 1960-1979 aient conduit à un déplacement de travailleurs dans les entreprises innovatrices. En fait, la majorité des innovations s'est traduite par des augmentations nettes des travailleurs à la production et de ceux qui n'y sont pas affectés; dans une proportion considérable d'innovations, par ailleurs, les effets sur le nombre de travailleurs ont été négligeables. Évidemment, l'utilisation de certaines de ces innovations par les firmes clientes pourrait bien influer sensiblement, et de diverses façons, sur le nombre de travailleurs employés.

Une très forte proportion (71 %) des innovations adoptées ont eu pour effet d'accroître les qualifications requises des travailleurs. La plupart des entreprises recyclent leurs travailleurs sur place, mais cette tendance est plus prononcée pour le cas des innovations de procédés et dans la catégorie des grandes entreprises. Pour leur part, les petites entreprises sont relativement plus portées à recruter à l'extérieur des travailleurs possédant déjà la compétence voulue. Cette tendance a été particulièrement marquée dans la catégorie des travailleurs non affectés à la production, pour laquelle 39 % des innovations des petites entreprises ont mené à l'embauche de nouveaux travailleurs de ce type; pour les grandes entreprises, la proportion correspondante a été de 24 %. Cette différence signifie que la grande entreprise montre plus de latitude et de flexibilité en matière de réorganisation interne.

Un très petit nombre d'entreprises optent pour le recyclage de leurs travailleurs à l'extérieur.

La plupart des entreprises n'ont pas fait breveter leurs principales innovations (32 % seulement de toutes les innovations indiquées l'ont été). En ce qui concerne les innovations brevetées, la plus forte variation tient à la taille de l'entreprise et aux caractéristiques du contrôle. Les taux de brevets accordés pour les innovations de produits et de procédés sont très semblables. Dans le cas des grandes entreprises, 48 % de leurs innovations ont été brevetées, mais les petites entreprises ne l'ont fait que pour 19 % seulement. Les taux de brevets accordés à des entreprises de propriété étrangère sont plus élevés que ceux des entreprises canadiennes. Cette différence peut s'expliquer par le fait que les taux d'obtention de brevets sont élevés pour les innovations plus coûteuses et pour celles qui se fondent sur une technologie importée. En outre, les taux ont nettement tendance à diminuer avec le temps.

Les entreprises répondantes ont été généralement inactives en ce qui concerne la vente ou l'octroi de licences relatives à leurs principales innovations. Seulement 15 % de la technologie utilisée pour ces innovations a été vendue ou a fait l'objet d'un octroi de licence par l'entreprise innovatrice. On ne note aucune différence dans cette tendance en ce qui touche le contrôle. Dans les cas où la technologie a été vendue ou concédée par licence, le revenu reçu par les entreprises répondantes représentait une proportion appréciable du coût total du développement de l'innovation et, en fait, couvrait environ la moitié des coûts de recherche et de développement. En chiffres absolus, les revenus que les entreprises canadiennes ont tiré de la vente de technologies ont été plutôt modestes.

En ce qui a trait aux problèmes auxquels les entreprises innovatrices se sont butées, aucun problème commun ne semble s'être posé. Dans le cas des innovations touchant aux procédés, dans les grandes entreprises et les entreprises de propriété étrangère, on invoque le plus souvent des problèmes techniques. En ce qui concerne les innovations liées aux produits et dans le cas des petites entreprises, ce sont les problèmes de commercialisation qui ont été le plus souvent mentionnés. Les entreprises canadiennes et les petites entreprises connaissent bien souvent des difficultés financières pour la production de leurs innovations. Les grandes entreprises font rarement allusion à des problèmes financiers, et les plus grandes ne le font jamais.

Les sources de financement des innovations

La plus grande partie des innovations déclarées (58 %) ont été financées entièrement à même les ressources internes.

Les sociétés mères et leurs filiables ont été les principales sources de financement externe pour le reste des innovations. Il n'y eût qu'une seule industrie -- celle de la fonte et de l'affinage des métaux -- où les apports intrasociété (y compris l'entreprise répondante) n'ont pas réussi à fournir au moins 70 % du financement total. Les grandes et moyennes entreprises réussissent ordinairement à s'autofinancer ou obtiennent des sociétés mères le paiement d'une plus forte proportion des coûts des innovations importantes que ne le font les petites entreprises.

Comme source de financement des innovations importantes qui ont été rapportées, les institutions bancaires jouent un rôle relativement peu important. Il n'y a qu'une seule industrie -- encore une fois, celle de la fonte et de l'affinage des métaux -- pour laquelle les banques ont joué un rôle important dans le financement d'innovations que n'aurait pu assurer entièrement l'entreprise en cause. Les petites entreprises ont plus recours aux banques que les moyennes et grandes entreprises.

Dans toutes les industries, sauf celle de la fonte et de l'affinage des métaux, le gouvernement fédéral a joué un rôle de premier plan, tant du point de vue de la proportion d'innovations supportées financièrement que de la proportion moyenne du financement total qu'il a assuré.

Les innovations d'entreprises canadiennes qui ont fait l'objet d'une aide gouvernementale ont été un peu plus nombreuses que celles des entreprises de propriété étrangère. En outre, le gouvernement a, dans l'ensemble, joué un rôle plus important dans le financement des innovations des petites et grandes entreprises que de celles de taille moyenne.

La nature et l'orientation du progrès technologique : comparaison entre les années 60 et 70

Il apparaît que les incertitudes suscitées par la performance médiocre de l'économie au cours des années 70 par rapport aux années 60 ont peut-être influé défavorablement sur certains aspects importants de la nature et de l'orientation du progrès technologique dans l'industrie canadienne, notamment dans la dernière partie des années 70. Par exemple, on pouvait noter que l'industrie tablait un peu plus sur des innovations dites d'amélioration, sur des innovations permettant un recouvrement plus rapide des coûts, et sur des innovations moins coûteuses. Au cours de la période 1960-1979, la proportion d'innovations importantes ayant été brevetées n'a pas été très élevée, mais par comparaison avec les années 60, elle a été encore plus faible au cours des années 70.

D'autre part, certains changements survenus au cours des années 70, indiquent un raffermissement de la base technologique des industries canadiennes examinées. Ainsi, les entreprises tant canadiennes qu'étrangères ont introduit un pourcentage plus élevé d'innovations fondées sur des technologies développées sur place. Bien que la proportion d'innovations imitatrices des grandes innovations introduites à l'étranger n'ait guère changé, elles se sont inspirées de plus en plus des technologies développées par des entreprises au Canada.

Enfin, les autres indicateurs de performance (par exemple, les exportations) n'ont pas dans l'ensemble, changé de façon appréciable au cours des années 70, même si l'on a pu noter des mouvements dans les indicateurs de performance visant différents types d'innovations et d'entreprises. Cependant, en 1978, la valeur médiane des ventes d'innovations touchant les produits était moins élevée pour les innovations introduites au cours des années 70 que pour celles qui l'avaient été durant les années 60. Ceci va de pair avec les dépenses médianes plus faibles notées pour les innovations développées et introduites au cours des années 70.

Conclusion

Nous tenons à insister sur le caractère préliminaire tant des données présentées dans cette étude que de leur analyse et de leur interprétation. Pour l'instant, notre but est d'abord de présenter, de la façon la plus complète possible, les résultats de notre enquête afin de recueillir commentaires et suggestions sur la présentation, l'analyse et l'interprétation de ces données. Les nombreux résultats de cette étude portant sur une large gamme de sujets sont de toute évidence interdépendants, mais leurs rapports n'ont pu être suffisamment explicités dans ce texte préliminaire. La présente conclusion se propose tout au plus d'inviter les commentaires et réactions; elle n'a pas vraiment pour but de résumer pleinement les répercussions possibles de nos résultats sur les nombreuses questions relatives à la politique industrielle. Nous croyons, cependant, que les renseignements analysés dans ce rapport peuvent jouer un rôle important dans l'analyse et l'évaluation des nombreuses questions de politique industrielle auxquelles devra faire face le Canada au cours des années 80. Nous n'envisageons pas pour autant, même dans le rapport final, de faire des recommandations explicites relative à la politique industrielle. Ce rapport n'est qu'une partie d'un programme de recherche plus vaste, déjà en cours au Conseil économique du Canada; il servira de base à un document à venir sur l'ensemble des politiques industrielles au Canada.

En regardant dans leur ensemble les nombreux résultats de cette étude, nous avons été frappés par le fait, maintes fois prouvé, qu'en ce qui a trait au processus d'innovation et de changement technologique dans les cinq industries étudiées, les entreprises cherchaient à raffermir leurs avantages comparatifs à l'intérieur même du milieu industriel canadien. Nos résultats indiquaient que tous les genres d'entreprises et d'industries ont utilisé une technologie canadienne pour développer un certain nombre d'innovations, une technologie importée pour en développer d'autres et, dans certains cas, une combinaison des deux types de technologies. Chaque entreprise analysée a mis au point de nouveaux produits et de nouveaux procédés, tout en améliorant ceux qu'elle avait déjà. Les entreprises consultées ont créé des innovations originales, mais elles ont imité aussi d'importantes innovations introduites à l'étranger. Les innovations imitatrices ont été mises au point tant à l'aide de la technologie importée que celle utilisée sur le plan interne. Quant aux innovations originales, elles reposaient sur une technologie tant intra-muros qu'acquise de l'extérieur.

Malgré les différences importantes relevées sur à peu près tous les aspects qui caractérisaient les diverses entreprises et industries, il nous a semblé que plusieurs facteurs économiques pouvaient expliquer la plupart de ces différences. Par exemple, les entreprises sous contrôle étranger ont eu recours plus souvent à une technologie importée parce qu'elles disposaient d'une source technologique extérieure plus riche, soit la société mère; mais, elles ont fait appel aussi, dans certains cas, à des sources sans lien de dépendance. On a pu remarquer que l'utilisation de technologies importées s'avérait plus fréquente lorsqu'elle servait à l'innovation de procédés. Par contre, les petites entreprises ont eu tendance à se spécialiser dans les innovations au niveau des produits. La diversité et la souplesse constatées sur les plans de l'innovation et du changement technologique dans les industries examinées laissent penser qu'il existe dans toutes les entreprises, un haut niveau de perfectionnement technologique. Si nous avions quelque inquiétude, elle proviendrait moins du degré de dépendance envers la technologie importée que sur le manque apparent de sources technologiques sans liens de dépendance pour les entreprises canadiennes. En somme, nous avons été impressionnés par les signes d'enrichissement progressif des bases technologiques que nous avons pu constater dans les cinq industries étudiées.

SUMMARY

This report focuses on the analysis of innovation and technological change processes in five Canadian industries: telecommunications equipment and components; electrical industrial equipment; plastics compounds and synthetic resins; non-ferrous smelting and refining; and crude petroleum exploration and production. One important aim of the report is to present basic information on the nature and characteristics of these processes in the Canadian firms and industries surveyed in respect of the major innovations introduced in the 1960-1979 period. It was felt that we lacked reasonably "hard" and detailed data on this very important subject. A second aim of the study was to isolate and analyse differences in respect of innovation and technological change among firms and industries with different characteristics. We discover some very distinct patterns in the technological change process, for example, among industries, between small and large firms, and between foreign-controlled Canadian firms and domestically-controlled Canadian firms. The results of the analysis are summarized below in broad outline. We hope the findings will make a real contribution to a better understanding of the important factors influencing innovation and technological change in Canadian industries and to the development of more effective industrial policies. The following summary highlights the overall findings, but not the inter-industry variations.

Basic Characteristics of Canadian Innovations

This report is based upon 283 major innovations, of which 82 were process and 201 were product. Of the 5 industries examined, 2 were product-oriented and 2 process-oriented.

New product and process innovations represent 60 per cent of reported innovations. That the firms consider improved products and processes to be important in the innovation process in Canada is shown by the fact that 40 per cent of reported major innovations are improvement innovations.

Similarly, imitative behaviour is also considered to be an important means of developing new and improved products and processes in Canadian industry. Slightly under half of the reported innovations were imitations of innovations introduced elsewhere in the world, while slightly over half were originals (world-firsts for Canada). Foreign-controlled firms more often imitated major innovations being produced abroad, whereas Canadian-controlled firms more often produced original innovations.

Process innovations were more often imitative than product innovations. Most of the imitative innovations by Canadian firms were based on innovations first introduced in the United States.

When innovations are characterized as either original or imitative, there is no implication that one is superior to the other. An "imitation" may well be more significant in terms of its impact on the productivity, competitiveness, and profitability of a firm in Canada than an "original" innovation. In fact, an imitation may represent a marked improvement over a "world-first" innovation.

Over half of the imitative innovations are based on technologies developed in-house by the reporting firm in Canada. Furthermore, 22 per cent of the original innovations were based in whole or in part on imported technologies.

Innovation is a time-consuming process. On average, firms spent $2\frac{1}{2}$ years developing their process innovations and $1\frac{3}{4}$ years developing their product innovations.

In general, firms opted for the development of innovations which had short pay-back periods. Over half of both product and process innovations had pay-back periods of less than 3 years.

Resources Required to Innovate, by Stage of the Technological Change Process

The technological change process is defined in terms of stages -- invention, innovation and diffusion. The report focuses on the activities of firms in respect of the first two stages. The innovative activities of firms are decomposed for analytical purposes into basic research, applied research, development, manufacturing start-up and marketing start-up.

Innovations are costly, and the process innovations are considerably more expensive to develop. Median expenditures on process innovations were $533,000 as compared to $213,000 for product innovations.

Development and manufacturing start-up expenditures are, on average, the major components of expenditures on the reported innovations -- with development costs being predominant for product innovations and manufacturing start-up costs for process innovations. In general, as the total cost of the innovation increases, the proportion of costs represented by manufacturing start-up costs also increases while the proportion represented by research and development costs decreases. A majority of the reported innovations involved no basic research, and a large proportion no applied research expenditures. There is significant inter-industry variation in these spending profiles.

The average spending profiles of innovations based on technology acquired from a source external to the firm (as opposed to those based on technology developed in-house) have relatively very low basic research components, lower applied research components, but only slightly lower development components. This reflects the fact that when firms do import technology, they are drawing on research undertaken externally, usually abroad. Whether or not such research could or would have been carried out in Canada in the absence of the technology imports is problematic.

R&D/sales ratios tend to fall continuously as firm size (number of employees) increases. Foreign-controlled firms of all sizes have lower R&D/sales ratios than their Canadian-controlled counterparts. This reflects the fact that the foreign-controlled firms are more active in the importation of technology into the firm, i.e., that they have general access to the R&D results of parent and affiliated firms abroad and do not attempt to duplicate this work in Canada.

R&D/sales ratios of firms vary significantly among industries -- averaging 9.6 per cent in telecommunications equipment and components, 3.2 per cent in electrical industrial equipment, 2.3 per cent in crude petroleum production, 1.3 per cent in plastics compounds and synthetic resins, and 1.3 per cent in smelting and refining.

Source of Technology for Canadian Innovations

Most (66 per cent) of the innovations reported in the survey were based upon technologies developed via R&D conducted in-house. A further 7 per cent of total innovations were based upon technologies developed through a combination of in-house R&D and externally acquired technologies. The remaining 27 per cent were based primarily on technologies acquired from sources external to the innovating firms. Overall, there does not appear to be an unbalanced reliance on imported technologies.

There is a marked tendency for the firms to develop the technology for product innovations in-house but to acquire technology for process innovations from external sources.

The innovations of Canadian-controlled firms are more often based on technologies developed in-house (82 per cent). Nevertheless, over half of the innovations of the foreign-controlled firms (54 per cent) are based on technologies developed in-house.

Canadian-controlled firms utilized imported technologies (in whole or in part) for 12 per cent of their product innovations and

40 per cent of their process innovations. The corresponding figures for the foreign-controlled firms' innovations are 39 per cent and 58 per cent, respectively.

Very small and very large foreign-controlled firms drew most heavily upon external sources of technology in whole or in part, acquiring technology from outside sources for 65 and 45 per cent of their innovations, respectively. Canadian-controlled firms of all sizes relatively rarely acquired technology from external sources for their major innovations. The same is true of medium-sized foreign-controlled firms.

The great majority of external technology sources utilized by the reporting firms are non-domestic, and most are U.S.-based. Only 15 per cent of all the technology transfers were internal to Canada, and most of these involved consultants.

For the 96 technology transfers, 55 per cent were intracorporate MNE transfers, the remaining 45 per cent occurring on an arm's-length basis. There were only 43 arm's-length transfers and these involved customers, suppliers, joint ventures and consultants.

Foreign-controlled firms, when importing technologies, drew heavily on parent and affiliated firms. Seventy per cent of their technology imports were made on an intracorporate MNE basis. It is notable that for 30 per cent of their technology transfers arm's-length sources were utilized. All but one of the technology transfers to Canadian-controlled firms were on an arm's-length basis.

Intracorporate technology transfer agreements often provided for continuous transfers of technology wherein the subsidiary is given access to future related developments in the technology made by the intracorporate source. The technology package transferred tended to be complete, providing for a full range of manufacturing and trademark rights. In addition, the agreements tended not to be written.

When operating on an arm's-length basis, the treatment of foreign-controlled firms is notably different from those cases where the technology transfer occurred on an intracorporate basis. Compared to arm's-length transfers to Canadian-controlled firms, the arm's-length transfers to the foreign-controlled firms are less complete, though they tend to be more frequently on a continuous basis than is the case for Canadian-controlled firms. Overall, the arm's-length transfers are less complete technology packages than the intracorporate transfers.

With respect to lag rates, i.e., the time elapsed from the first world launch (products) or use (processes) of an innovation to its first launch or use by the reporting firm, the evidence is rather mixed. For product innovations lag rates in introducing the innovations into Canada were shorter when they were developed via imported technologies. This was also true for the process innovations of Canadian-controlled firms. However, lag rates on the process innovations of foreign-controlled firms were shorter when the technology was developed in-house. Regardless of the source of technology, the foreign-controlled firms were quicker to imitate process innovations than were Canadian-controlled firms. This was not true of product innovations.

Technological Change in Canadian- and Foreign-Controlled Firms

Canadian-controlled firms represent 48 per cent of all reporting firms. The remaining 52 per cent are foreign-controlled, with U.S.-controlled firms being dominant. On average, the foreign-controlled firms are much larger in terms of both sales and number of employees than the Canadian-controlled firms.

Foreign-controlled firms accounted for 70 per cent of all process innovations. This partially reflects their dominant position in the process-oriented industries. In addition, they produced slightly more new process innovations than Canadian-controlled firms. The latter, however, produced a higher proportion of new product innovations than did the foreign-controlled firms. Foreign-controlled firms accounted for 52 per cent of all product innovations.

Foreign-controlled firms devoted longer periods of time to the development of both product and process innovations, the difference being greater for processes. In general, the foreign-controlled firms were also quicker to adopt process innovations first introduced abroad.

The R&D spending component of foreign-controlled firms is smaller than that of Canadian-controlled firms primarily because the research component of the innovations of foreign-controlled firms is smaller, particularly in respect of process innovations. These differences primarily reflect the large size of the innovations of the foreign-controlled firms and their greater propensity to import technologies. The very small research component for innovations based on imported technologies is a result of the access these firms have to the R&D findings of their parent firms.

Even where the innovations are based on imported technologies, considerable amounts of R&D are involved, except in the case of the process innovations of the foreign-controlled firms where virtually all of the expenditures of the firm occur at the manufacturing start-up stage in many cases.

In any event, average expenditures on the innovations of the foreign-controlled firms are significantly larger in absolute terms than those of Canadian-controlled firms for both total expenditures and expenditures at each stage of the innovation process.

The pay-back periods associated with the innovations of foreign-controlled firms are longer than for innovations of Canadian-controlled firms.

The product innovations of foreign-controlled firms tend to have larger sales values than those of the Canadian-controlled firms, even per dollar of expenditure on the innovation.

In 1978, 68 per cent of the product innovations of Canadian-controlled firms were being exported as compared to 57 per cent for the foreign-controlled firms' product innovations. Differences between the two types of firms arise because of the extremely poor export performance of product innovations based on externally acquired technology. However, when exports do occur, the median values of exports of the product innovations of foreign-controlled firms exceed those of the Canadian controlled firms.

Technological Change in Small and Large Firms

Most of the firms in the sample (52 per cent) are small in size, employing 100 or fewer people; only 15 per cent of the reporting firms employ more than 500 people.

Overall, the small firms tend to be product innovation-oriented (79 per cent of their innovations are products), and large firms process innovation-oriented (54 per cent of their innovations are processes). This is generally true at the industry level as well.

Small Canadian-controlled firms are the most product innovation-oriented of all types of firms and spend longer periods of time developing and commercializing their products than do the small foreign-controlled firms. Large Canadian-controlled firms are also more product innovation-oriented than their foreign-controlled counterparts. These firms actually spend more time developing and commercializing their product innovations than their process innovations. This characteristic distinguishes them from all other types of firm.

The small and the large foreign-controlled firms are more process-oriented than their Canadian-controlled counterparts in these respects.

Small firms, regardless of origin of control of the firm, are clearly opting for innovations which have pay-back periods of less than 3 years. Large firms, on the other hand, introduced innovations which had longer pay-back periods.

For small firms, development costs are not only the largest component of their spending on product innovations, but also on process innovations. For large firms, development costs are the largest component of spending on product innovations, manufacturing start-up costs dominating spending on process innovations. In fact, for the process innovations of large firms, research spending tends to represent a larger proportion of spending on these innovations than developmental spending. The importance of research spending by large firms on process innovations may account for their longer development and commercialization periods.

Large firms, regardless of origin of control, show the greatest propensity to fund 100 per cent of the cost of their innovations wholly internally. Small Canadian- and foreign-controlled firms and medium-sized foreign-controlled firms also funded more than 50 per cent of their innovations wholly internally: medium-sized Canadian-controlled firms, however, tended to rely more upon external sources of funding.

Small and medium-sized Canadian-controlled firms drew upon a large number of external sources with no single source providing a very large proportion of the funds required to finance the innovations. Foreign-controlled firms of all sizes also used a diversity of external sources of funding, the most frequently used of which, however, provided substantial proportions of the funds required for the innovation.

Canadian-controlled firms show higher levels of R&D intensity than foreign-controlled firms, i.e., they tended to spend more on R&D activities per employee in the field of interest. Also, R&D intensity tends to decrease as firm size increases in the case of the Canadian-controlled firms. The foreign-controlled firms, however, show no trend towards an increase or decrease in R&D intensity as firm size changes.

The propensity to export product innovations is high among all sizes of firms, although the largest firms had by far the highest propensity. When firms did export, larger proportions of the total sales of the product innovations of the large firms were exported than was the case for small firms. It is apparent, therefore, that scale considerations play a role in the ability of firms to export.

Issues Concerning the Management and Impact of Innovations

All reporting firms were strongly affected by a desire to take advantage of new technological capabilities in the decision to innovate. Market-related factors were also frequently cited. The product innovation-oriented firms and industries, particularly small and Canadian-controlled firms, tended to develop innovations designed to fill market niches. Large firms, on the other hand, were more oriented towards increasing their market shares. Product innovations were also strongly affected by interactions with customers.

Process innovation-oriented firms, particularly foreign-controlled and large firms, were more concerned with reducing energy and labour requirements than were other types of firms, although even then these factors were not often cited.

A desire to improve the quality of the products covered by the innovations was cited as an important motivating factor in the decision to innovate for about 20 per cent of the innovations of Canadian- and foreign-controlled firms. Some specialized factors in the decision to innovate show industry-specific variation. For example, the two industries which indicated the greatest sensitivity to foreign and domestic competition -- the plastics compounds and synthetic resins and electrical industrial equipment industries -- also most frequently cited the importance of a desire to improve the quality of the products covered by the innovation.

The sources of ideas and information used by firms in the course of developing their innovations show strong differences across firm types. Canadian-controlled firms relied heavily upon customers as sources of ideas for their product innovations and upon suppliers for process innovations. In contrast, foreign-controlled firms were heavily dependent upon parent and affiliated firms for ideas and information relating to their product and process innovations. This reliance upon intracorporate sources is particularly marked in the case of the innovations of foreign-controlled firms based upon externally acquired technology.

It is apparent, therefore, that parent firms are not only important external sources of technology, but also play a major role in idea-generation and problem-solving for the innovations of their subsidiaries. In most cases, Canadian-controlled firms lack appropriate intracorporate technology channels and so deal primarily at arm's-length. Intracorporate flows of information and technology are facilitated through frequency of use and intimacy of interaction to a much greater degree than in an arm's-length type relationship.

In terms of impacts of reported innovations on numbers of workers, net increases in the numbers of both production and non-production workers predominated, followed by negligible changes in the numbers employed. These effects were strongest in respect of product innovations and innovations of small firms.

In the case of some process innovations, however, net decreases in the number of workers employed are worthy of note; 20 per cent of the process innovations led to a net decrease in the number of production workers. Also, the introduction of 11 per cent of the innovations of large firms led to a net decrease in the number of production workers. In neither case was there a significant number of innovations leading to net decreases in the number of non-production workers.

These results indicate that it is very unlikely, on balance, the major innovations introduced during the 1960-79 period led to displacement of labour in the innovating firms. In fact, the majority of the innovations resulted in net increases in production and non-production workers and a further large proportion had negligible effects on the number of workers. Of course, the utilization of some of these innovations by customer firms may well be significantly affecting numbers of employed workers in those firms in quite different ways.

A very high proportion (71 per cent) of the innovations introduced led to an icrease in skill requirements of workers. Most firms tended to retrain their workers internally, although this tendency is most marked in the case of process innovations and for the innovations of large firms. Small firms, on the other hand, had a relatively greater tendency to hire workers with the requisite skills from outside the firm. This propensity is particularly marked in the case of non-production workers, where 39 per cent of the innovations of small firms led to the hiring of new non-production workers; the corresponding figure for large firms is 24 per cent. These differences reflect the fact that the large firm has greater scope and flexibility for internal reorganization.

Very few firms used the option of sending existing workers outside for retraining.

Most firms did not patent their major innovations (only 32 per cent of all reported innovations were patented). For those innovations that were patented, the strongest variation in patenting rates is exhibited in relation to firm size and control characteristics. Patenting rates on product and process innovations are very similar. Forty-eight per cent of the innovations of large firms were patented, but small firms patented only 19 per cent of their innovations. Patenting rates of foreign-controlled firms are higher than those of Canadian-controlled firms. This difference is influenced by the fact that patenting rates are high for the more costly innovations and for innovations based on imported technology. Also, there is a strong tendency for patenting rates to decline over time.

The reporting firms are generally inactive in the sale or licensing of technology for their major innovations. Only 15 per cent of the technology for the reported innovations was sold or licensed by the innovating firm. There is no difference in this tendency across control. In those cases where technology was sold or licensed, the income received by the reporting firms represented a significant proportion of the total cost of developing the innovation and, in fact, covered roughly half the R&D costs. In absolute terms the receipts from the sale of technologies of the Canadian-controlled firms were quite small.

With regard to problems encountered by firms in innovating, no single problem stands out as causing particular difficulty. Technical problems were most frequently cited in the case of process innovations, innovations of large firms and of foreign-controlled firms, and for new innovations. For product innovations and innovations of small firms, marketing problems were most frequently cited. Canadian-controlled firms and small firms most often experienced financial difficulties in producing their innovations. Large firms seldom cited financial problems, and the largest firms never did.

Sources of Funds for Innovations

Most of the reported innovations (58 per cent) were wholly funded internally.

Parent and affiliated firms were major external sources of funding even in the case of the remaining 42 per cent of the innovations. In only one industry -- smelting and refining -- did intracorporate sources (including the reporting firm) fail to provide at least 70 per cent of total funding. Large and medium-sized firms tended to generate internally or obtain from parents larger proportions of the costs of major innovations requiring external funding than did small firms.

The banking system as a source of funding of major reported innovations is relatively unimportant. In only one industry -- again, smelting and refining -- were banks important to the funding of innovations not wholly funded internally. Small firms relied upon banks to a greater extent than did medium-sized and large firms.

In all industries except smelting and refining the federal government played a distinctly important role, both in terms of the proportion of innovations that it supported and the average proportion of total funding it provided.

Slightly more innovations of Canadian-controlled firms received some government funding than innovations of foreign-controlled firms. Also, government played, on the whole, a more important role in funding innovations of small and large firms than it did those of medium-sized firms.

The Nature and Direction of Technological Change: 1960 vs. 1970s

There is some evidence that the uncertainties generated by the poorer economic performance of the economy in the 1970s compared to the 1960s might be adversely affecting some important aspects of the nature and direction of technological change in Canadian industry, particularly in the latter half of the 1970s. For example, there were trends toward a slightly greater reliance on improvement innovations, innovations with faster pay-backs, and less costly innovations. The proportion of major innovations being patented was not very high over the 1960-79 period, but it was lower in the 1970s as compared to the 1960s.

On the other hand, some of the changes in the 1970s indicate a strengthening of the technological bases of the Canadian industries examined. For example, both Canadian- and foreign-controlled firms were introducing larger percentages of innovations based on technologies developed in-house. Although the proportion of innovations which were in imitation of major innovations being introduced abroad did not change much, the imitative innovations were increasingly being based upon technologies generated by the innovating firms in Canada.

Finally, other performance indicators (e.g., exports) did not change significantly overall in the 1970s, though there were shifts in the performance indicators for different types of innovation and firm. However, median 1978 sales values of product innovations were lower for innovations introduced in the 1970s than for those introduced in the 1960s. This parallels the finding of lower median expenditures on the innovations being developed and introduced in the 1970s.

Conclusions

We stress the preliminary nature of this report in terms of the findings presented and their analysis and interpretation. At this point in time, the main purpose of the report is to present the findings of the survey in a complete enough manner to elicit comments and advice on the form, analysis, and interpretation of the data presented. The numerous findings in the report on a wide range of subjects are obviously interrelated in ways which have not been sufficiently drawn out in the preliminary report. The concluding chapter is most tentative and preliminary and was designed more to elicit comments and reactions than to represent a serious attempt to fully summarize the implications of the findings in the report for the numerous relevant industrial policy issues. We believe the information presented and analysed in the report can play an important role in helping us to analyse and assess the many industrial policy issues facing Canada in the 1980s. It is not our intention, even in the final report, to make explicit industrial policy recommendations. This report is part of broader program of basic research underway at the Council, designed to form the basis of an Economic Council of Canada document on Canadian industrial policies.

In viewing the many findings of the report as a whole in respect of the innovation and technological change processes in the five industries, we were most impressed with the extensive evidence that firms were pursuing their comparative advantages within the Canadian industrial framework. We found that all types of firms and industries analysed were utilizing domestically-generated technologies to develop some innovations, importing technologies to develop other innovations, and employing combinations of internally-generated and externally-acquired technologies in still other cases. We found all firms were developing both new products and processes and improving on their existing ones. Firms were producing original innovations and imitating important innovations being introduced abroad. Firms were imitating innovations via the utilization of imported technologies and technologies developed in-house, and were also producing original innovations based on both internally developed and externally acquired technologies.

There were differences in degree in almost all these aspects for firms and industries with different characteristics, but it appears to us that there were sound economic factors in play capable of explaining many of these differences. For one example, foreign-controlled firms more often utilized imported technologies because they had available to them a rich external technology source -- the parent firm; but even so, the foreign-controlled firms also obtained technologies from arm's-length sources in particular cases. Utilization of imported technologies by all firms was more common in the case of process technologies. Small firms, on the other hand, specialized in product innovations. The evidence of diversity and flexibility in respect of innovation and technological change in the industries examined on the part of all the firms suggests a high degree of technological sophistication. If we had one concern, it related not to the degree of reliance on imported technologies in the industries examined, but rather to the apparent lack of arm's-length technology <u>sources</u> available to Canadian firms. Finally, we were impressed with the evidence of a strengthening in the technological bases of the five industries over time.

Chapter I

INTRODUCTION

This report analyses innovation and technological change processes in five Canadian industries* over the last two decades. We do not attempt to measure innovation and technological change per se or to gauge its profitability. Our aim was to study the process as such and to isolate and analyse the factors affecting innovation and technological change in Canadian industries. The analysis primarily focuses on the role of the firm in respect of technological advance and hence the strong emphasis on innovation. Innovation is the domain of the firm -- the process whereby it applies its technology to the development and introduction of new and improved products and processes of production.

The report is primarily based on our survey of innovation in the five industries. Firms were asked to identify and describe their innovations -- major new or improved products or production processes -- which had most contributed to their profitability. A great deal of information was provided on the major innovations introduced in the industries during the 1960-79 period. Information was sought on the nature of the innovations, expenditures on the innovations and their composition, the sources of the technology for the innovations, the nature of the technology transfers, the basic characteristics of the innovations, whether or not the innovation was original to Canada, the sources of funding for the innovations, factors affecting the decision to innovate, etc. In addition, basic information on the control of the firm, its sales, R&D spending, employment of scientists and engineers, etc., was also requested. The survey was sent to all firms which we could identify as being active in the five industries.* The overall response rate was 41 per cent (170 firms responded, producing information on 291 innovations). Given that the survey was so demanding, the response rate was excellent. It provided us with an in-depth and original body of data and information for analysing

* Telecommunications Equipment and Components, Electrical Industrial Equipment, Plastics Compounds and Synthetic Resins, Nonferrous Smelting and Refining, and Crude Petroleum Production.

innovation and technological change in the five industries. In addition, we carried out over 50 personal interviews with both respondent and non-respondent firms as a follow-up to the mail questionnaire.

In the report, we treat technological change as a process, whereby technology (know-how) is either generated internally via the in-house R&D work of the firm or obtained externally via arrangements with other firms or institutions, and then applied by the innovating firm to develop and commercialize the innovation in question. The formal innovation phase focuses on the development of the innovation and its first commercial launch (product innovations) onto the market or its first use (process innovations) in the operations of the firm. The process of technological change does not end with the innovation process. The diffusion of the innovation within and among firms, and in some cases to other industries, is also an important part of the process of technological change, but our report does not examine diffusion processes. This important aspect of technological advance has been studied for a number of Canadian innovations. Finally, we should point out that when a firm simply purchases new machinery and equipment, whether domestically or from abroad, it is purchasing the technology embodied in the hardware, but such purely commercial purchases are not included in the analysis of technological change processes in this report.

Chapter II of the report examines the nature and basic characteristics of the innovations. Are they product or process innovations, and do they amount to new products or processes or improvements in existing products or processes? Are the innovations world-first innovations (originals) or are they in imitation of major innovations already introduced in industries abroad (imitations)? How quickly do we adopt innovations first introduced abroad? How long does it take us to develop our major profitable innovations and how long does it take for the investment in the development of the innovations to pay back? We find significant and more or less predictable variations in these basic characteristics among the industries studied.

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* The Questionnaire itself and detailed information on the response rate are presented in Appendix I.

Chapter III decomposes the technological change process into specific stages for analytical purposes. We then examine total expenditures on the innovations and the components of total expenditures (basic research, applied research, development, manufacturing start-up, and marketing start-up). The composition of the expenditures is emphasized as well as the differences in the expenditure profiles among different types of firms and industries. Again, we find significant differences for firms and industries with different characteristics. In the second part of the chapter we examine the research and development activities of the different types of firms in the five industries.

Chapter IV deals with the question of the source of the technology for the major innovations of firms in Canadian industry. In discussions of industrial policy issues in Canada there has been a tendency to confuse the generation of a technology with innovation as such. Technology is know-how, and it should not be confused with the hardware (machinery and equipment) which embodies the technology or with the innovation which applies the technology. We hope this report will help to dispell this confusion and thus contribute to a better understanding of the technological change process in Canada and the factors influencing it. We begin by examining the sources of the technology for our major innovations. To what extent was the technology developed in-house as opposed to being acquired externally? When firms do turn to external sources, what are the specific sources (parent firm, customers, suppliers, consultants, etc.)? When firms import technology, what mechanisms do they rely upon (parent-subsidiary transfers, joint ventures, arm's-length licenses, etc.)? Finally, what sort of conditions are attached to technologies which are acquired externally? Again, the analysis is comparative, with a heavy focus on differences between Canadian- and foreign-controlled firms.

Chapters V and VI analyse technological change processes along the lines set out in the earlier chapters in detail, for Canadian- and foreign-controlled firms and for small and large firms. Significant differences in patterns of innovation and technological change are discovered for the different types of firms analysed.

Chapter VII moves away from the more technical issues and examines the sources of ideas for innovations and the major factors influencing the decision of firms to develop and introduce their reported innovations. In addition, the effect of the innovation on the skill requirements of the work force and on numbers employed is analysed, as is the broad nature of the problems firms experienced in the development of their major innovations. The extent to which firms patent their innovations is also examined. The analysis of these factors also stresses the differences among firms and industries with different characteristics. In a similar vein, Chapter VIII examines the sources of funds for major Canadian innovations generally and with particular reference to the role of government in providing support for innovations in the five industries.

Chapter IX examines the technological change process over time to determine whether or not there is evidence of any change in the nature and direction of technological advance in the 1970s compared to the 1960s. Some evidence is found of a deterioration in the technological change process in the 1970s.

In the concluding chapter, we attempt to apply the findings in the body of the report to the analysis of some of the important current industrial policy issues facing Canada.

The preliminary nature of this report needs to be stressed. The report covers an extremely broad range of issues, all of which deserve much more detailed analysis than was possible within the scope of one overview report. We have tended to generalize in the report on the basis of differences in ratios for different types of firm, innovation and industry. At times, the differences were not large and the number of observations were small. We have not performed tests to determine statistical significance for the many relationships described in the report. We have always reported numbers of observations. In addition, we have not made any reference in the preliminary report to the existing relevant literature on the many subjects discussed. The main purpose of the report at this point is primarily to expose the information and broad findings of the survey and to indicate in an exemplary way how these findings can be related to the analysis of current industrial policy issues.

Chapter II

AN OVERVIEW OF INNOVATION
IN FIVE CANADIAN INDUSTRIES

The Nature of the Innovations: Product vs. Process Innovations

The innovations reported in the survey can be described in a number of ways. Is the innovation a product or process, new or improved, original or an imitation of an existing innovation? How long did it take to develop, how long to become profitable? What was the primary source of the innovations' technology? This chapter will focus on differences in these and other characteristics of the innovations among the five industries being examined.

Of the 283 innovations which were coded for analysis in this report, 82 were process innovations and 201 were product innovations. Thus the majority (71 per cent) of the innovations reported are new or improved products. These product innovations are, in the main, "producers' goods", in that they are destined to be inputs into the production processes of other firms, and in this way contribute to productivity in Canadian industries. Table 1 presents the innovations distributed between new and improved products and processes.

The table isolates a number of important characteristics of the reported innovations -- in many cases an innovation cannot be characterized as simply a product or process. For example, with respect to the total "product" innovations, as characterized by the reporting firms, 32 per cent of these also involved the use of a new production process in order to effect the innovation. Often, the characterization of product or process innovations relates more to the motivation or primary objective of the firm in innovating rather than to any strict technological distinction. The firm might specifically want to produce a new product which might or might not require a significant alteration in production processes. On the other hand, in developing a more efficient production process, the firm is constantly on the lookout for ways of improving the quality of the products flowing from the process.

Table 1

PRODUCT AND PROCESS INNOVATIONS BY TYPE

Type	Number	% of Total
A new product requiring development of a new production process	66	23
A new product using an existing or slightly modified production process	66	23
An improved product requiring development of a new production process	25	9
An improved product utilizing modifications to an existing production process	44	16
A new production process for existing or improved products	39	14
An improved production process for existing or improved products	43	15
Total Innovations	283	100

The types of innovations listed in Table 1 were characterized as new or improved by the reporting firms themselves. New innovations, as opposed to improvement innovations, are assumed to represent the more radical innovations. It was left to the firm to make the judgment as to whether the innovation amounted to a new product or process or simply an improvement in the range of existing products or processes on the market.

A number of tests were run, using other information from the survey, to determine whether the firms' characterizations of their innovations were analytically meaningful. The results of these tests indicate the distinctions are analytically sound. For example, on average, new products and processes required longer periods of time to develop and commercialize than improved products and processes. Similarly, new products and processes, on average, required proportionally more research work and more development work than improved products and processes. As other examples, new process innovations much more often raised labour skill requirements in the firm than process improvements and new innovations more often led to spin-off innovative developments than did improvement innovations. In general, these differences between new and improved innovations were more marked for process than for product innovations.

For all reported innovations, 46 per cent were characterized as new product innovations, 25 per cent improved product innovations, 14 per cent new process innovations, and 15 per cent improved process innovations.

The development of product and process innovations is examined, by industry, in Table 2. There is significant variation in the tendencies of the different industries to develop product as opposed to process innovations, and these variations are in the directions one would expect given the nature of the industries and their technological characteristics.

Table 2

PRODUCT AND PROCESS INNOVATIONS BY INDUSTRY

Industry	Product Innovations as % of Total Innovations			Process Innovations as % of Total Innovations		
	Product	New	Improved	Process	New	Improved
	-- (%) --			-- (%) --		
Telecommunications Equipment and Components	91	(72)	(19)	9	(4)	(6)
Electrical Industrial Equipment	90	(41)	(49)	10	(3)	(7)
Plastics Compounds and Synthetic Resins	70	(45)	(25)	30	(18)	(13)
Smelting and Refining	21	(15)	(6)	79	(45)	(33)
Crude Petroleum Exploration and Production	10	(7)	(3)	90	(37)	(53)

Original vs. Imitative Innovations

The issue of whether the reported innovations are "original" or "imitations" is separate from the issue of whether the products and processes are new or improved. Innovation is often understood to refer to the first commercial launch or use of a new or improved product or process anywhere in the world. We will call such innovations original (or world-first) innovations. The subsequent spread of the innovation throughout the world is then classified as the international diffusion of the innovation. But from the viewpoint of a national industry, the first commercial launch or use of an innovation in a country is also very often termed innovation from the national viewpoint. We will call innovations with a prior commercialization or first use "imitations". However, the characterization of certain innovations as "imitations" should not be interpreted to imply these innovations are in some sense inferior to those characterized as "original". The term imitation simply indicates the fact that the innovation or a very similar one was introduced elsewhere in the world prior to being introduced by the reporting firm. An "imitation" may well be more significant in terms of its effects on the productivity, competitiveness and profitability of the firm in Canada than some or all of the "original" innovations. The "imitation" may, in fact, represent a marked improvement over the "world-first" innovation.

Table 3, below, sets out the composition of the reported product and process innovations in terms of original vs. imitations. Reported innovations represent "world firsts" in slightly over half the product innovations and slightly less than half of the process innovations.

Table 3

PRODUCT AND PROCESS INNOVATIONS: ORIGINAL VS. IMITATIONS

	All Innovations	Product Innovations		Process Innovations	
		Number	% of Product Innovations	Number	% of Process Innovations
Original	148	109	55%	39	48%
Imitations	133	90	45%	43	52%
Total	281	199	100%	82	100%

A high percentage of both the product and process innovations reported by firms as their major innovations are original innovations, in the sense that the reporting firm was not aware of any other firm commercializing or using the reported innovation or a very similar one prior to its own first commercial launch or use. Process innovations are less often original and more often imitative of process innovations introduced elsewhere.

Country of First Launch or Use for Imitative Innovations

Table 4, set out below, presents the country of first commercial launch or use of the imitative innovations. As expected, over half of these innovations were first launched or used in the United States -- an important source of innovations which Canadian firms imitate one way or another.

Table 4

COUNTRY OF FIRST COMMERCIAL LAUNCH OR USE

Country	Number of Innovations	% of Total
United States	78	58.6
Canada*	11	8.3
West Germany	9	6.8
Scandinavia	5	3.8
France	5	3.8
United Kingdom	2	1.5
Other European	5	3.8
Japan	5	3.8
Other Countries**	13	9.8
Total	133	100.0

*Note that a small number of reported innovations were imitations of innovations which had their first commercial launch or use in Canada. These innovations are part of the diffusion process in Canada. It is also possible that some of the innovations where the first launch or use was abroad also had a first launch in Canada prior to that of the reporting firm, but these cases cannot be isolated. The number of these would also be small, as checks indicated that most of these imitations were by Canadian subsidiaries introducing innovations developed by parent companies, so the first launch in Canada would be by the Canadian subsidiary.

**Includes countries not listed plus cases where country of first launch is not known.

Sources of Technology for Original and Imitative Innovations

We have also analysed the sources of technology (know-how) for the two types of innovations (original and imitative). As expected, a high proportion of the 148 original innovations (78 per cent) were primarily based on technology developed within the firm (Table 5). Even so, it is significant that 22 per cent of the original innovations were based in whole or in part on technology obtained externally (usually abroad) from other firms or institutions. One might expect, on the other hand, that our imitations would primarily rely on technology obtained from outside the firm (e.g., from foreign firms). However, it turns out that more than half (52 per cent) of the 133 innovations characterized as imitations represent cases where Canadian firms recognized important innovations being developed elsewhere and used their resources to copy (and possibly improve on) these innovations, based on technology developed in-house for that purpose.

Table 5

SOURCES OF TECHNOLOGY FOR ORIGINAL AND IMITATIVE INNOVATIONS

Primary Source of Technology	Original Innovations		Imitative Innovations	
	Number	Per Cent	Number	Per Cent
Developed In-House via R&D	116	78	69	52
Acquired Wholly or in Part from Outside*	32	22	64	48
Total	148	100	133	100

*Of the 32 original innovations, 22 were based primarily on externally acquired technology and 10 were based on both externally acquired technology and internally developed technology to an important degree. Of the 64 imitations, 55 were based on externally acquired technology and 9 were based on a combination of externally acquired and internally generated technology.

Only 64 of the 133 imitations represent cases where the firm externally acquired technology for the innovations being copied. These latter 64 innovations, along with 32 original innovations using externally acquired technology, add to the 96 innovations (out of 283) where the primary source of the technology for the innovations was obtained from outside the innovating firm via formal arrangements. Even with respect to the 96 innovations, 19 of them were based only in part on imported technology. Just 77 of the 283 major innovations reported in the survey were based wholly on imported technology -- i.e., 27 per cent (see Chapter IV, Table 1). These data demonstrate that original (world-first) innovations can be developed using externally acquired technology and that over half of our imitative innovations are based on technology developed in-house by the reporting firm in Canada.

Another issue in respect of imitative innovations being introduced into Canada relates to the control of the firms introducing them. Of the 133 imitations, 49 (37 per cent) were innovations by Canadian-controlled firms, while 84 (63 per cent) were by foreign-controlled firms. Foreign-controlled firms in Canada no doubt have better access to information on innovations being developed abroad, particularly in the countries of their parent firms and the countries where their parents have other subsidiaries or affiliates operating. Furthermore, these firms have access to the technologies of their parents and affiliates abroad. On the other hand, of the 148 original innovations (world firsts), 71 or 48 per cent were by Canadian-controlled firms, and 77 or 52 per cent were by foreign-controlled firms. One would expect that foreign subsidiaries in Canada would play the greater role in introducing into Canada innovations first developed abroad. What is perhaps more surprising is the fact that close to half of the innovations reported by foreign-controlled firms are original innovations -- i.e., had not been first developed or commercialized abroad. The analysis of foreign-controlled vs. Canadian-controlled firms in the technological change process is set out in detail in Chapter V.

Performance Indicators:
Original vs. Imitations

Do original innovations as compared to imitations have different characteristics? Are they more important or valuable? In this connection, we carried out four tests. First, sales of original product innovations are compared to sales of product imitations. Second, the percentages of product and process innovations which resulted in further research and development effort to produce additional innovations are compared for original vs. imitative innovations. Third, the percentage of innovations which raised the skill requirements of the labour force are compared for original and imitative innovations. Fourth, a number of tests relating to the "exportability" of original and imitative product innovations were carried out.

It should first be pointed out that the total costs of developing and introducing the two types of innovations do not, on average, differ greatly. The 108 imitative innovations had an average total cost of $346 million as compared to $285 million for the 124 originals. Thus the mean expenditure on imitations is considerably larger than the mean expenditure on originals. However, median expenditures on original and imitative innovations are $279,500 and $245,000, respectively. This indicates the presence of a number of imitative innovations which required extremely large total expenditures to bring the innovations onto the market or into operation in the firm.

We have information on the sales of product innovations in 1978 for a large number of the original (79) and the imitative (65) product innovations. A comparison of the median sales values for these two types of innovations shows a median sales value of $831 thousand for original product innovations and $1 million for product imitations (see Table 6). Though these estimates are rather rough and ready, there is a clear tendency for innovations first introduced abroad and then imitated in Canadian industry to generate more sales than is the case for innovations where the first world launch was Canada. This is not a particularly surprising result, since the former innovations are based on innovations which are presumably attracting considerable attention and represent innovations with more proven markets than would be the case for world-first Canadian innovations.

A second test of original and imitative innovations relates to the question of spin-offs -- i.e., the percentage of reported innovations (original vs. imitations) which led to additional (spin-off) research and development work by the innovating firm to produce additional innovations. It was found that 61 per cent of the original process innovations led to spin-off R&D work and further innovations, while a higher percentage (67 per cent) of imitative process innovations led to such spin-offs. In this respect, imitations receive a plus in terms of performance indicators. On the other hand, the situation is reversed in respect of product innovations -- 76 per cent of original product innovations led to spin-offs while only 70 per cent of imitative product innovations led to such spin-off results. Thus, overall the differences are not significant.

A third test relates to the percentage of reported innovations which had the effect of raising the skill requirements of the labour force of the firms involved in producing the products or employing the processes in production systems. This is a measure of the depth of the innovations. It was found that 67 per cent of the original innovations raised labour force skill requirements in the innovating firms, as compared to 75 per cent for imitative innovations.

We can also look at the "exportability" of our innovations in respect of our product innovations. Roughly 61 per cent of all product innovations developed during the 1960-1978 period were, to some degree, being exported in 1978. This proportion may seem rather low in light of the fact that we are dealing with major innovations of reporting firms. In looking further into this issue, we find that 66 per cent of the original product innovations were exported to some degree in 1978 as compared to only 55 per cent for imitative product innovations. Hence the "exportability" of original product innovations appears to be greater than that of imitative product innovations. Furthermore, the average percentage of sales of these innovations going to exports is also higher for original product innovations (60 per cent vs. only 38 per cent for imitative product innovations). Finally, the median value of exports of original product innovations ($500,000) is also greater than for imitative product innovations ($350,000). These tests are summarized in Table 6.

Table 6

PERFORMANCE INDICATORS FOR ORIGINAL VS. IMITATIVE INNOVATIONS

Test	Original No. of Cases	Original % or Value	Imitative No. of Cases	Imitative % or Value
Median Sales Value in 1978 of Product Innovations ($000)	79	$831	65	$1,000
Percentage of Innovations Leading to Spin-Offs:				
All Innovations	145	72%	131	69%
Process Innovations	38	61%	42	67%
Product Innovations	107	76%	89	70%
Percentage of Innovations Raising Labour Force Skill Requirements	97	67%	99	75%
Percentage of Product Innovations Leading to Exports in 1978	79	66%	65	55%
Mean of Ratios of Export Values to Sales of Product Innovations in 1978 for All Product Innovations Where Export Values Positive	52	60%	36	38%
Median Export Values for All Product Innovations Where Export Value Positive ($000)	52	$500	36	$350

In summary, it appears there are some differences in performance between these two types of innovations. Imitative innovations perform better in terms of sales but do not perform so well in terms of exports. At least some of the imitative innovations appear to be playing more of an import-replacement rather than an export-stimulation role. As discussed above, imitative innovations are more often based on imported technology than is the case with original innovations, and this does affect the exportability of the product innovations.* Questions

*We should bear in mind that the exportability and sales tests could not be applied to process innovations.

relating to the significant differences between innovations where the technology was obtained externally and innovations where the technology was developed within the firm are discussed in the following chapters. This latter distinction, it turns out, is the more important one from an economic and technological viewpoint, and some of the differences uncovered here (e.g., the differences in exportability) can be traced to the fact that a larger proportion of imitative innovations are based on imported technology.

Inter-Industry Variations: Originals vs. Imitations

The breakdown of innovations between original and imitative innovations by industry is set out in the following table. There is considerable variation in the proportion of total innovations by industry which are imitations as opposed to original innovations.

Table 7

ORIGINAL VS. IMITATIVE INNOVATIONS BY INDUSTRY

Industry	Number of Original Innovations	Number of Imitative Innovations	Imitative as % of All Innovations
Telecommunications Equipment and Components	66	40	38
Electrical Industrial Equipment	31	37	54
Plastics Compounds and Synthetic Resins	15	25	63
Smelting and Refining	15	18	55
Crude Petroleum Exploration and Production	19	11	37

The two industries with the lowest proportion of imitations are telecommunications equipment and crude petroleum exploration and production, though for different reasons. The rapidity of technological advance in telecommunications equipment offers great scope and opportunity for the development of original innovations employing new technology, while in crude petroleum the reported innovations are primarily by large firms developing process innovations to meet their own specific operating needs. In any event, the imitation process is clearly an important one for the five industries; in fact, for electrical industrial equipment, pastics compounds, and smelting and refining, imitative innovations represent in excess of 50 per cent of the major innovations introduced during the 1960-79 period by the reporting firms in these industries.

Lag Rates in the Introduction of Imitative Innovations

One important question in relation to imitations, which it will be recalled represented close to half of our reported major innovations (133 vs. 148 original innovations), relates to how quickly important innovations first developed abroad are being introduced into our Canadian industries. This issue can be analysed by studying the lag between the first commercial launch (products) or use (processes) of the innovation by the reporting firm and the first world launch or use of the innovation. Table 8 sets out lag rates by industry. The lags in introducing the innovations into Canada seem long. Extremely long lags on some of the innovations are biasing the averages upwards, but even the median lags for both product and process innovations are five years. In subsequent chapters, data on these lags are analysed in detail for Canadian- and foreign-controlled firms, for innovations employing different methods of obtaining or developing the technology for the innovations, for small vs. large firms, etc. The speed at which important innovations being developed abroad are introduced into Canada is an important aspect of technological change processes in Canadian industries. There is great variability in lag rates among the industries. Lag rates are discussed in detail in Chapter IV.

Table 8

LAGS IN THE INTRODUCTION OF INNOVATIONS DEVELOPED ABROAD INTO CANADIAN INDUSTRY, BY INDUSTRY

	Number of Innovations	Average No. of Years Between First World Launch or Use and First Launch or Use by Reporting Firm
Product Innovation	77	7.4
Process Innovation	34	8.7
Total Innovations	111	7.8
Telecommunications Equipment and Components		
Product Innovation	31	5.5
Process Innovation	5	5.8
Total Innovations	36	5.5
Electrical Industrial Equipment		
Product Innovation	27	9.3
Process Innovation	1	5.0
Total Innovations	28	9.1
Plastics Compounds and Synthetic Resins		
Product Innovation	14	7.5
Process Innovation	7	7.3
Total Innovations	21	7.4
Smelting and Refining		
Product Innovation	3	10.3
Process Innovation	12	11.8
Total Innovations	15	11.5
Crude Petroleum Exploration and Production		
Product Innovation	1	5.0
Process Innovation	9	7.7
Total Innovations	10	7.4

Commercialization and Pay-Back Periods for Major Innovations

Two other basic aspects of the innovation process are examined in this chapter -- the length of time required to develop innovations and the pay-back period.

The average length of time from the first significant employment of human and capital resources on the innovation to its first commercial launch (product innovations) or use (process innovations) for all innovations was two years.

Table 9

AVERAGE NUMBER OF MONTHS TO FIRST COMMERCIAL LAUNCH OR FIRST USE*

	Number of Months
All Innovations	24
Product Innovations	21
Process Innovations	30

*Average number of months from first significant employment of human or capital resources on the innovations to their first commercial launch (products) or first use (processes).

As expected, on average, process innovations take significantly longer to develop and introduce into production processes than product innovations. In addition, as will be seen in the next chapter, the total expenditures required to develop process innovations are, on average, significantly greater than those required for product innovations. The commercialization periods for each of the five industries separately are given in Table 10.

Table 10

AVERAGE NUMBER OF MONTHS TO
FIRST COMMERCIAL LAUNCH OR FIRST USE,
BY INDUSTRY

	All Innovations			Product Innovations			Process Innovations		
		Months to Innovate			Months to Innovate			Months to Innovate	
Industry	No.	Average	Median	No.	Average	Median	No.	Average	Median
Telecommunications Equipment and Components	108	20.1	15	90	20.3	15	10	18.0	12
Electrical Industrial Equipment	65	17.4	13	58	17.5	14	7	16.4	12
Plastics Compounds and Synthetic Resins	40	28.6	24	28	28.8	18	12	28.3	24
Smelting and Refining	32	33.0	24	7	24.6	13	25	35.4	24
Crude Petroleum Exploration and Production	26	34.1	24	1	12.0	12	25	35.0	24

Information on the length of time for the firm's expenditures on research and development to pay-off after the first launch or use of the innovations was also sought in the survey. Firms were asked to estimate whether their R&D expenditures on the innovations were recouped in less than 3 years, 3 to 5 years, or more than 5 years. The results are given in Table 11.

Table 11

PAY-BACK PERIOD FOR REPORTED INNOVATIONS

Pay-Back Period	All Innovations		Product Innovations		Process Innovations	
	No.	%	No.	%	No.	%
Less than 3 years	142	54	103	55	39	53
3-5 years	78	30	58	31	20	27
More than 5 years	43	16	28	15	15	20

For all innovations, and product and process innovations separately, investment in the R&D undertaken was recouped in less than 3 years in slightly over 50 per cent of the cases. A larger proportion of process innovations had pay-back periods of more than 5 years. In general, the fact that over 50 per cent of the reported innovations had a pay-back period of less than 3 years is rather surprising. Table 12 sets out the pay-back periods by industry.

There is great variability in the pay-back periods among industries, with crude petroleum having the longest pay-back periods and plastic compounds the shortest.

Table 12

PAY-BACK PERIOD FOR REPORTED INNOVATIONS BY INDUSTRY

Industry	Pay-Back Period					
	Less than 3 Years		3-5 Years		More than 5 Years	
	No.	%	No.	%	No.	%
Telecommunications Equipment and Components	56	55	32	31	14	14
Electrical Industrial Equipment	37	57	20	31	8	12
Plastics Compounds and Synthetic Resins	22	61	10	28	4	11
Smelting and Refining	16	53	12	40	2	7
Crude Petroleum Exploration and Production	10	38	4	15	12	46

Summary

A large proportion of reported innovations are product innovations (71 per cent), but with great inter-industry variation -- e.g., 91 per cent of the innovations in telecommunications equipment were product innovations as compared to 10 per cent for crude petroleum production.

New product and process innovations (as opposed to improvement innovations) represented 60 per cent of reported innovations. But clearly, improvement innovations (40 per cent of all reported major innovations) are an important aspect of the innovation process in Canadian industries.

Slightly over half of reported innovations were originals (world-firsts) and slightly under half were imitations (based on innovations developed elsewhere in the world).

Process innovations are more often imitative than product innovations.

Canadian firms most often imitate innovations first developed in the United States.

Only 27 per cent of reported innovations were primarily based on externally acquired technology.

Even when Canadian firms imitate foreign innovations, they develop the technology for the innovations in-house in Canada in the majority (52 per cent) of the cases.

Foreign-controlled firms more often imitate major innovations being developed abroad than do Canadian-controlled firms.

There are not very significant differences in the performance of original and imitative innovations, except that original innovations demonstrate better export performance (owing to the very weak export performance of innovations based on imported technology).

The tendency to develop innovations in imitation of developments around the world varies among industries, but over half of the reported innovations in three of the five industries were imitative innovations.

The average time required to imitate or copy a significant innovation developed abroad is long and varies among industries -- from 5 years in telecommunications equipment to 11 years in smelting and refining.

Innovation is a time-consuming process -- on average it required 1 3/4 years to develop the product innovations and 2 1/2 years to develop the process innovations.

Over half of our reported innovations, both product and process, had pay-back periods of less than three years.

Chapter III

THE STAGES OF THE TECHNOLOGICAL CHANGE PROCESS AND RESOURCES REQUIRED TO INNOVATE

Stages of the Technological Change Process

As a process, technological change can usefully be decomposed into a number of stages, from basic research through to marketing start-up or even further (i.e., to the diffusion of innovations within firms and industries). The entire process is described in this study as the technological change process, the stages of which are set out conceptually in the following diagram.

Chart 1

STAGES OF THE TECHNOLOGICAL CHANGE PROCESS

1. Basic Research 2. Applied Research	Invention
3. Development 4. Manufacturing Start-Up 5. Marketing Start-Up	Innovation
6. Spread of the Innovation Within Firms and Industries	Diffusion

This report deals with the first five stages of the process of technological change. The data collected do not allow for an analysis of the diffusion of the innovations in Canada.

Separating the technological change process into stages can be extremely useful for analytical purposes, so long as it is not treated in too literal or rigid a manner. For example, these stages phase into one another and for many innovations it is very difficult, if not impossible, to draw a precise line between them. Also, not all of the stages need be carried out within a single firm or institution (for example, firms in Canada in fact carry out little basic research themselves). Finally, these stages need not occur in the order listed -- a firm undertaking developmental work may be forced to undertake further applied research at some later point if technical problems arise, or a firm commercializing an innovation may find it necessary to undertake further developmental work owing to market reactions to the innovation.

In any event, analysis of the components of the total expenditures incurred by firms in the development of a large number of major innovations in the five industries gives us a great deal of original and useful information on the structure of technological change processes and how they vary for different types of innovations, firms, and industries. There has been considerable disagreement, for example, even over the basic question of the relative costs to firms of the different stages involved in the development and commercialization of innovations.

Expenditures on Major Innovations

Table 1, set out below, presents information on the expenditures incurred in the development of the major innovations reported upon in the survey for cases where the firms were able to estimate their expenditures for each of the five stages.

Table 1

EXPENDITURES ON THE DEVELOPMENT OF
INNOVATIONS BY PROCESS STAGE
(234 INNOVATIONS)*

Stage	All Innovations $ Millions	All Innovations % Total		Product $ Million	Product % Product		Process $ Million	Process % Process	
1. Basic Research	18.8	3.0	9.8	5.2	4.0	14.3	13.6	2.7	8.6
2. Applied Research	42.8	6.8		13.6	10.3		29.2	5.9	
3. Development[a]	202.8	32.1		52.4	39.8		150.4	30.1	
4. Manufacturing Start-up[b]	348.0	55.1		53.6	40.8		294.4	58.9	
5. Marketing Start-up	18.8	3.0		6.8	5.2		11.9	2.4	
Total	631.2	100.0		131.6	100.0		499.5	100.0	

*Estimates of expenditure profiles were available for 237 of the 283 coded innovations. However, 3 of these were dropped from the analysis because total expenditures and the expenditures for manufacturing start-up were so very large they seriously skewed the results. Included are 169 product innovations and 65 process innovations.

a Includes engineering, layout, design, prototype construction, pilot plant construction, testing, market evaluations, etc.

b Includes tooling, plant arrangement, construction of additional plant, acquisition of equipment, etc.

The above data on expenditures are in current dollars and represent the total costs of developing and launching the innovations ($631 million). The percentages of total costs incurred for the different stages are also computed in the table. These percentages are based on total spending incurred by all reporting firms together for each stage in the development of the 234 innovations.

As expected, basic research expenditures represent only a small proportion of the total expenditures required to develop and commercialize the major innovations of the reporting firms.* Research expenditures represented slightly less than 10 per cent, and R&D expenditures together represented 42 per cent of total expenditures, as compared to manufacturing start-up costs which amounted to 55 per

*It is likely that the research spending reported as basic research in the survey is closer to the concept of fundamental or long-run research than to the strict definition of basic research.

cent of expenditures. Marketing start-up expenditures were also relatively minor, reflecting to a large extent the nature of the innovations being produced by the five industries under study. When these expenditures are examined for product and process innovations separately, we find R&D expenditures represent 54 per cent of total expenditures for product innovations and 39 per cent for process innovations. These relative expenditures are, of course, extremely variable from innovation to innovation. However, in total, including all five industries, the research and development spending required to develop and commercialize the 234 innovations represented 42 per cent of total expenditures. This means that for many innovations, the largest part of the required expenditures to develop and commercialize innovations was still to come at the end of the R&D stage, particularly in the case of process innovations. Although these data represent the total costs of developing the innovations by stage of process, the spending proportions are not a good measure of the average percentages of total spending firms devote to research, development, and manufacturing start-up. These average ratios are discussed in a later section of this chapter.

The above analysis is based on 234 reported innovations. In addition we have expenditure profiles for three other innovations, two by foreign-controlled firms (one product, one process), and one by a Canadian-controlled firm (process). These innovations were excluded from the value-based tables discussed above because they so badly skewed the results by virtue of their enormous relative size and one of these included expenditures of a firm other than the reporting firm. The three innovations together had total costs amounting to close to $700 million. Their inclusion in the tables would more than double total spending on all innovations together, and the proportion of manufacturing start-up expenditures for all innovations would rise to over 75 per cent (all other components becoming insignificant). Because these three costly innovations so badly skewed the results of the value-based tables in this and the following chapters, they have been excluded from the analysis of the costs of innovations and the value-based comparisons of innovation costs for different types of firms and industries.

The Average Costs of Major Innovations

Innovation is a very expensive proposition. Table 2 sets out the average total costs of all product and process innovations reported, and the average costs by industry. The values are in current dollars.

Table 2

AVERAGE TOTAL COSTS OF PRODUCT AND PROCESS INNOVATIONS (234 INNOVATIONS)

	Product Innovations			Process Innovations		
	No. of Innovations	Mean	Median	No. of Innovations	Mean	Median
		($000's)			($000's)	
All Industries	169	779	213	65	7,684	533
Telecommunications Equipment and Components	88	551	225	9	1,222	315
Electrical Industrial Equipment	46	733	185	6	103	16
Plastics Compounds and Synthetic Resins	26	651	85	10	14,303	1,030
Smelting and Refining	6	4,693	450	21	8,431	925
Crude Petroleum Production	0	--	--	19	8,831	575

On average, the process innovations are considerably more costly to develop and introduce. There is also marked variability in costs among industries. In general, the mean values are considerably greater than the median values, indicating the presence of small numbers of extremely costly innovations. The costs of product innovations reported ranged from a low of $2,000, to two innovations which cost roughly $15 million to develop and bring onto the market. The process innovations ranged in cost from a low of $5,000 to two innovations costing $90 million plus to develop and bring into production. These examples exclude the three largest innovations discussed in the previous section.

Expenditure Profiles: The Average Spending of Firms on the Stages of the Technological Change Process

We have to this point expressed the expenditures of firms for each stage of the process as a percentage of the total spending of firms in the development and introduction of the innovations -- which gives us a picture of the resources required to produce the innovations in total. However, these proportions are strongly influenced by the very large innovations which, for example, have such heavy manufacturing start-up costs. To get a better fix on the average relative spending by firms in producing the 237 innovations, the means of the spending ratios per innovation are set out in the table below for the stages of the process. When average expenditure ratios are analysed, the relative importance of research (basic and applied) rises to 19.4 per cent and developmental spending to 39.4 per cent. This increase reflects the fact that the very large innovations with relatively high manufacturing start-up costs are given the same weight as all the other projects in constructing the relative spending ratios, as opposed to Table 1 which was weighted per dollar of expenditure. The increase in the R&D components and the decline in the manufacturing component is seen for both product and process innovations.

Table 3

AVERAGE OF RATIOS OF EXPENDITURES BY STAGE TO TOTAL EXPENDITURES PER INNOVATION
(Mean Percentages)

Stage	All Innovations		Product		Process	
	(237)		(170)		(67)	
1. Basic Research	6.3	19.4	7.3	20.0	3.7	17.8
2. Applied Research	13.1		12.7		14.1	
3. Development	39.4		43.0		30.3	
4. Manufacturing Start-Up	33.7		27.5		49.6	
5. Marketing Start-Up	7.5		9.5		2.3	
Total	100.0		100.0		100.0	

Basic research remains the minor component of the expenditures of firms in the five industries, averaging 6.3 per cent per innovation. Of the 237 innovations analysed, 143 innovations (or 60 per cent) involved no basic research spending. This was true for both product and process innovations. The relative importance of applied research in total expenditures on innovations was greater (averaging 13.1 per cent per innovation), but the percentage of innovations which required no applied research, though lower, is still relatively high at 48 per cent for product innovations and 32 per cent for process innovations. On average, development expenditures emerge as the single most significant cost for product innovations, manufacturing start-up costs as the most significant component for process innovations. Only 26 of the innovations reported involved no specific development expenditures and only 12 innovations reported no research or development expenditures.

Manufacturing start-up costs are of almost equal importance with developmental costs (averaging 33.7 per cent per innovation) and, as expected, these start-up costs are relatively more important for process innovations where they exceed the importance of developmental spending by a considerable margin. Marketing costs do not turn out to be very important in the development of the innovations in the industries under study.

The following conclusions can be drawn from the data to this point. Research expenditures are a relatively small component of R&D spending for the reporting firms. It is the developmental and manufacturing start-up costs which are of major importance. However, the extreme variability of the ratios has also been noted. Existing studies have found the relative importance of R&D expenditures to vary from 10 per cent to 80 per cent, and this type of volatility is observed among the reported innovations. But, on average, we find that R&D expenditures amount to about 63 per cent for product innovations and 48 per cent for process innovations.* The more general conclusions we derive, however, are that R&D expenditures are relatively more important and manufacturing start-up expenditures less important for product than for process innovations, and that process innovations are significantly more expensive to develop.

The question of how the relative importance of the different stages of the technological change process differs by industry is also important. The following table sets out the average of the relative expenditure ratios per innovation for each of the five industries.

Table 4

AVERAGE OF RATIOS OF EXPENDITURES BY STAGE TO TOTAL EXPENDITURES PER INNOVATION, BY INDUSTRY

Industry	Basic Research	Applied Research	Development	(R&D)	Manufacturing Start-Up	Marketing Start-Up
Telecommunications Equipment and Components			-- (%) --			
Product (88)	5.0	12.7	50.9	(68.6)	23.9	7.5
Process (9)	6.0	13.7	30.5	(50.3)	47.0	2.7
Electrical Industrial Equipment						
Product (46)	7.9	9.5	40.4	(57.8)	32.1	10.0
Process (6)	5.6	13.8	14.0	(33.5)	64.7	1.9
Plastics Compounds and Synthetic Resins						
Product (26)	15.6	20.4	25.8	(61.7)	21.5	16.7
Process (10)	2.2	15.9	9.5	(27.6)	67.4	5.0
Smelting and Refining						
Product (7)	2.2	5.7	25.1	(33.0)	65.3	1.7
Process (22)	3.1	10.4	19.3	(32.7)	64.3	3.0
Crude Petroleum Production						
Product (0)	-	-	-	(-)	-	-
Process (20)	3.4	17.6	57.7	(78.8)	21.2	0

*It should also be noted that differences in definitions will affect these results. For example, in our definition of development spending we include design and testing (see Table 1).

The industry which most clearly stands out is crude petroleum exploration and production, which has such large developmental expenditures. This, of course, is inherent in the nature of the production process in the industry. The innovations reported in the survey are in support of the industry's exploration and development work (e.g., the development of the tar sands), and thus it is no surprise that development costs alone are as high as 58 per cent of total expenditures. Manufacturing start-up costs are insignificant for this sector of the vertically integrated petroleum industry. If the analysis of innovations were extended to include the refining as well as crude petroleum production sector, the relative importance of developmental expenditures in total expenditures would no doubt decline. Thus this industry should be treated as an exception in respect of its relative spending on innovations when compared to manufacturing industries.

With respect to the other four industries, there are still significant differences in their relative average spending profiles in the development and commercialization of innovations. For example, research spending (basic and applied) on product innovations is of significantly greater importance in the plastic compounds and synthetic resins industry than in any of the other four industries. The ratio of R&D spending to total spending per product innovation averages 33 per cent in smelting and refining, 58 per cent in electrical industrial equipment, 62 per cent in plastic compounds and synthetic resins, and 69 percent in telecommunications equipment. For process innovations, R&D spending ranges from 28 per cent in plastic compounds to 79 per cent in crude petroleum production. The variability of the expenditure profiles among industries is such that in crude petroleum the dominant expenditure category is developmental expenditures; in the process-oriented smelting and refining industry, manufacturing start-up expenditures dominate; in plastic compounds research costs dominate for product innovations, manufacturing start-up for process innovations; and in the product-oriented electrical industrial equipment and telecommunications equipment and components sectors, development expenditures are the single largest category. These variations reflect differences in the nature of the innovations being developed in the different industries.

Table 5

AVERAGE OF RATIOS OF EXPENDITURES BY STAGE
TO TOTAL EXPENDITURES PER INNOVATION,
BY SIZE OF TOTAL EXPENDITURES

	$0 to $50K		Over $50K to $260K		Over $260K to $1M		Over $1M to $5M		Over $5M	
	Product (37)	Process (10)	Product (56)	Process (14)	Product (49)	Process (13)	Product (21)	Process (15)	Product (7)	Process (15)
	-- %--									
Basic Research	8.2	4.4	4.9	8.3	11.3	1.1	4.9	3.2	0	1.6
Applied Research	15.2	15.7	11.4	15.9	12.6	12.0	13.1	17.7	10.2	9.6
Development	40.8	53.5	48.5	27.3	44.0	35.1	34.5	16.8	29.2	27.1
Research and Development	64.3	73.6	64.8	51.6	67.9	48.1	52.4	37.7	39.4	38.4
Manufacturing Start-Up	23.2	26.4	24.9	44.8	23.9	45.8	40.2	62.0	57.5	60.4
Marketing Start-Up	12.5	0	10.3	3.7	8.3	6.0	7.3	0.3	3.1	1.2

The relative spending profiles by stage of the technological change process are sensitive to the size (total cost) of the innovations. In general, the greater the total expenditures required to innovate, the relatively less important are R&D expenditures, on average, in the total costs of innovating. For product innovations, as we move from small- to medium-sized innovations in terms of total expenditures, the research spending component falls and the development spending component rises so relative R&D costs remain fairly constant. However, for product innovations requiring total expenditures in excess of $1 million, the R&D component falls, particularly for innovations requiring more than $5 million to develop and commercialize. The manufacturing start-up component exceeds the development spending component for product innovations in excess of $1 million and reaches 57.5 per cent for innovations requiring total spending in excess of $5 million. For process innovations, the R&D component falls continuously over the smaller and medium-size groups. For all process innovations in excess of $1 million, manufacturing start-up costs represent over 60 per cent of the total costs of the innovations.

The relative expenditure profiles by stage of the innovation process, for different types of innovations, firms, and industries, give us a great deal of valuable information about technological change processes in a Canadian context. One particularly interesting comparison involving these profiles relates to differences between innovations where the primary source of the technology for the innovations was external to the firm and those where the technology was developed in-house. The following table sets out this information for product and process innovations separately.

Table 6

AVERAGE OF RATIOS OF EXPENDITURES BY STAGE
TO TOTAL EXPENDITURES PER INNOVATION,
BY SOURCE OF TECHNOLOGY

	Technology Obtained Externally			Technology Developed In-House			Partly External and Partly In-House		
	Product	Process	All	Product	Process	All	Product	Process	All
	(36)	(22)	(58)	(130)	(33)	(163)	(4)	(12)	(16)
				-- %--					
Basic Research	1.8	0	1.1	8.7	7.1	8.2	9.6	3.8	5.2
Applied Research	6.5	6.2	6.4	14.8	15.5	14.9	1.3	24.8	19.0
Development	42.7	29.8	37.8	42.8	29.8	40.1	53.5	32.9	38.0
Research and Development	51.0	36.0	45.3	66.3	51.4	63.3	64.5	61.5	62.2
Manufacturing Start-Up	35.2	62.3	45.5	25.4	45.8	29.5	25.8	36.6	33.9
Marketing Start-Up	13.7	1.7	9.2	8.4	2.8	7.2	9.7	1.9	3.8

As expected, where the technology for the innovation was obtained externally by agreement or arrangement, the research component of total expenditures is very low. In fact, for the 58 innovations where the technology was obtained from other firms or institutions, 54 of them involved no basic research spending and 40 involved no applied research on the part of the recipient firms. Only 13 of these innovations involved no development expenditures. In fact, 15 per cent of these 58 innovations involved no R&D spending at all on the part of the firms. In contrast, less than 2 per cent of the 163 innovations developed in-house involved no R&D spending. Even so, 50 per cent of the 163 innovations developed in-house required no basic research and 35 per cent required no applied research spending.

Despite the above, considerable absolute amounts of R&D spending were required in the development of the 58 innovations based on imported technology. For example, average R&D spending on innovations where the technology was primarily obtained externally was $614,000 as compared to average R&D spending of $1,045,000 on innovations where the technology was developed in-house. Thus average R&D spending on the former type of innovations amounts to a little less than 60 per cent of that for innovations where the technology was developed in-house, most of it being developmental work on the imported technology. A higher proportion of innovations based on imported technology are process innovations (37 per cent) than is the case for innovations based on technology developed in-house (only 20 per cent were process innovations). The general conclusion which emerges from the analysis of these expenditure profiles is that the importation of technology by agreement or arrangement with other firms or institutions acts as a strong substitute for research spending but has little effect on the relative proportion of developmental spending required to launch the resulting product innovations into the operations of the innovating firms. Whether or not in the absence of the importation of the technology the innovations would have been introduced into Canadian industries as quickly as they were (or at all) is difficult to say. In our interview we found that some of the firms were not in the position to generate such technologies in-house, and that other firms, even if they believed they had the capacity to develop the technology, decided it was more cost efficient to acquire it externally.

We have full expenditure profiles for 16 innovations where important parts of the technology were obtained externally and other important parts developed in-house. These innovations have expenditure profiles closer to those of innovations where the technology was developed completely in-house. These are the largest innovations -- in terms of total expenditures for their development they cost over twice as much to develop on average as the other two types of innovations. Twelve of these sixteen innovations were process innovations. Thus in this category we are mainly dealing with a small number of large technologically sophisticated process innovations.

Two further comparisons of these spending profiles by stage of the innovation process are of interest -- original vs. imitative innovations, and the innovations of Canadian- vs. foreign-controlled firms. In respect of imitations vs. original innovations, there are not the significant differences between expenditure profiles that were found for innovations with different sources for the technology. However, the research component for original innovations is higher than for imitative innovations (particularly for process innovations), and the development component of original process innovations is quite a bit higher than for imitative process innovations. But the R&D component of imitative innovations is still quite high, reflecting in important part the fact discussed above that over half of the imitations were based on technology developed in-house. Chapter IV analyses the innovations based on imported technology in great detail.

Table 7

AVERAGE OF RATIOS OF EXPENDITURES BY STAGE
TO TOTAL EXPENDITURES PER INNOVATION --
ORIGINAL vs. IMITATIVE INNOVATIONS

	Imitations			Originals		
	All	Product	Process	All	Product	Process
	(110)	(77)	(33)	(125)	(91)	(34)
			-- % --			
Basic Research	5.6	6.1	4.3	7.0	8.4	3.1
Applied Research	11.4	11.8	10.5	14.8	13.8	17.6
Development	38.3	43.1	27.2	40.1	42.6	33.3
Research and Development	55.3	61.0	42.0	61.9	64.9	54.0
Manufacturing Start-Up	36.3	27.8	56.1	31.3	26.8	43.3
Marketing Start-Up	8.4	11.1	1.9	6.8	8.4	2.7

Finally, one can compare the expenditure profiles for innovations of Canadian-controlled firms with those of foreign-controlled firms. Process innovations by Canadian-controlled firms represent a lower proportion (22 per cent) of their total innovations than is the case for foreign-controlled firms (32 per cent of foreign-controlled firms' innovations are process innovations). In general, innovations by Canadian-controlled firms have a higher research component and a lower manufacturing start-up component. Developmental spending on process innovations by foreign-controlled firms also represents a significantly lower component of total expenditures than is the case for process innovations by Canadian-controlled firms. However, it should be noted that average total expenditures on innovations by foreign-controlled firms are significantly greater than average expenditures on the innovations of Canadian-controlled firms. For example, the median value for total expenditures on innovations by foreign-controlled firms was $380,000 as compared to $165,000 for Canadian-controlled firms' innovations. As shown above, the relative spending profiles by stage of the innovation process are very sensitive to the size (total cost) of the innovations. Equally important, of course, a higher percentage of the innovations of foreign-controlled firms are based on imported technology. Expenditures reported for foreign- and Canadian-controlled firms' innovations do not include payments made for technology obtained externally. These issues are analysed further in Chapter V.

Table 8

AVERAGE OF RATIOS OF EXPENDITURES BY STAGE
TO TOTAL EXPENDITURES PER INNOVATION--
CANADIAN-CONTROLLED vs. FOREIGN-CONTROLLED FIRMS

	Innovations of Canadian-Controlled Firms			Innovations of Foreign-Controlled Firms		
	All	Product	Process	All	Product	Process
	(101)	(78)	(23)	(136)	(92)	(44)
	-- % --					
Basic Research	9.2	10.2	6.0	4.1	4.8	2.4
Applied Research	14.5	14.8	13.3	12.1	11.0	14.6
Development	40.6	42.4	34.5	38.5	43.5	28.1
Research and Development	64.3	67.4	53.9	54.7	59.3	45.1
Manufacturing Start-Up	27.7	23.4	42.2	38.2	30.9	53.5
Marketing Start-Up	8.0	9.2	3.9	7.1	9.9	1.4

Research and Development Effort
in Canadian Industries

In most analyses of innovation and technological change, great emphasis has been placed on research and development spending (R&D). In fact, the R&D construct may not be a very appropriate one for analysing some aspects of the technological change process in Canadian industry. On conceptual grounds, research and development spending overlaps the stages of the technological change process outlined at the beginning of this chapter. Basic and applied research spending is directed to invention -- the creation of technology (know-how) in respect of the production of goods and services. On the other hand, developmental spending is geared to putting this know-how into practice by developing new and improved products or services, production processes or systems. Thus developmental activity is the beginning of the formal innovation process. One must be careful in concentrating on the R&D construct not to confuse, as is commonly done, technology and innovation. As stressed above, a large number of major innovations being introduced into Canadian industries required little or no basic or even applied research. Furthermore, innovations, both original and imitative, were based on imported technology in a number of cases, which clearly substituted for in-house research effort. This calls into question the widely held view in Canada that in-house research is a necessary and sufficient prerequisite to the development of major innovations in Canadian industry.

Simply because in-house research is often a small component of total expenditures by firms in developing their innovations certainly does not mean that research is an unimportant aspect of the process of technological change -- it clearly is of vital importance. But, in many cases, current levels of technology in the firm allow it to develop innovations without significant additional expenditures on research. At other times, firms can draw on available research results and findings of other firms and institutions in developing their innovations. At times firms purchase required technology and at other times they copy and improve upon innovations introduced elsewhere, employing their own in-house expertise to this end. Though research is vitally important to the broad process of innovation and technological advance, specific innovations need not necessarily be based on research developed in-house and the research component of spending on major innovations need not be very large. What firms have stressed in discussing their innovation performance is the necessity to maintain over time a high level of technological expertise and awareness within the firm, regardless of the source of the technology. Firms also stressed the overriding importance to them of the application of technology in the innovation process, regardless of the source of the technology.

Virtually all the major innovations developed in our five Canadian industries required significant amounts of development work. Developmental work is the dominant cost of most product innovations, while manufacturing start-up costs tend to dominate in the development of process innovations. The two together tend to account for over 70 per cent of the expenditures of firms on their innovations. Therefore, as an index of innovation in these industries, developmental and related manufacturing start-up costs associated with innovations would no doubt represent a superior index to the commonly used R&D indexes. Of course, the problem with the former construct is that manufacturing start-up costs associated with innovations are difficult to measure and are not normally calculated by firms on an annual basis, whereas R&D spending data are normally more available. R&D spending in total is an important component of total expenditures on innovation, but in treating R&D to sales ratios as indexes of innovation effort, we should be aware of the above issues in respect of sources of technology and the post-R&D stages of the innovation process.

In 1978, the R&D spending to sales ratio for the 134 firms reporting this data averaged 5.8 per cent -- a surprisingly high ratio. Furthermore, 14 of these firms reported no R&D spending in 1978, introducing a downward bias in the ratio. On the other hand, some firms with very high ratios in 1978 are pulling the average upwards. For this reason, both the average and median values for the ratios are reported in the table below setting out the R&D/sales ratios of the 5 industries separately. As is evident, the high average R&D/sales ratio for all the reporting firms is primarily the result of the extensive R&D and innovation activity underway in the telecommunications equipment industry.

Because in analysing R&D/sales ratios we are dealing with numbers of firms, and because some firms did not report R&D spending or sales data, the number of observations in some of the reporting industries is rather small. However, with the exception of crude petroleum, the total number of firms in those industries with a small number of reporting firms, is also quite small. In any event, these ratios, particularly the median values, seem to give a fairly good picture of the relative R&D/sales ratios in the five industries. The relative ratios no doubt reflect to a great degree the technological opportunities in the different industries which strongly influence the amounts of R&D which firms will find it worthwhile to undertake.

Table 9

AVERAGE OF FIRMS' R&D SPENDING TO SALES RATIOS IN 1978
BY INDUSTRY *

	No. of Firms Reporting **	R&D/Sales Ratios Mean (%)	R&D/Sales Ratios Median (%)
Telecommunications Equipment and Components	56	9.6	3.3
Electrical Industrial Equipment	41	3.2	1.7
Plastic Compounds and Synthetic Resins	16	1.3	0.8
Smelting and Refining	10	1.3	0.5
Crude Petroleum Exploration and Development	10	2.3	0.5

*These ratios are not the total R&D/sales ratios of the firms but, rather, their R&D/sales ratios in the fields (industries) listed. A number of the reporting firms do R&D and have sales in other (usually related) fields.

**These are the firms that reported both R&D and sales figures for 1978. Of these reporting firms, 3 in telecommunications equipment, 4 in crude petroleum, 1 in plastic compounds, and 6 in electrical industrial equipment reported no R&D spending in 1978.

Another strong influence on R&D/sales ratios is firm size. Our data show a strong and persistent tendency for R&D/sales ratios to decline with the employment size in 1978 of the reporting firm (Table 10). This tendency persists if size is measured by sales values. For example, the 38 firms with sales of $2 million or less in 1978 had an average R&D/sales ratio of 11.3 per cent as compared to an average of 3.6 per cent for the 96 firms with sales in excess of $2 million.

Table 10

AVERAGE OF FIRMS' R&D/SALES RATIOS
BY SIZE OF FIRMS IN 1978

Number of Employees in the Field	Number of Firms	R&D/Sales Ratios Average	Median
		(%)	(%)
50 employees or less	48	8.9	3.8
100 employees or less	69	8.0	4.7
200 employees or less	93	6.7	3.2
500 employees or less	115	6.0	2.8
More than 500 employees	20	4.0	0.8
All Firms	134	5.8	2.4

Table 11 presents the R&D/sales ratios of firms by size category for each industry separately.

Table 11

AVERAGE OF FIRM'S R&D TO SALES RATIOS
BY FIRM SIZE, BY INDUSTRY

Industry	No. of Employees in Field 50 or Less	100 or Less	500 or Less	Over 500
	-- (%) --			
Telecommunications Equipment and Components	13.8	12.1	10.0	5.6
Electrical Industrial Equipment	5.3	5.0	3.6	1.0
Plastics Compounds and Synthetic Resins	0.5	0.6	1.3	0.4
Smelting and Refining	4.3	4.3	1.9	0.7
Crude Petroleum Production	3.6	2.5	2.2	2.6

One issue which has received great attention in Canada is whether the R&D to sales ratios of Canadian-controlled firms are greater than those of foreign-controlled firms. Table 12 presents these ratios by industry. R&D/sales ratios of Canadian-controlled firms are considerably higher than those of foreign-controlled firms.

Table 12

AVERAGES OF FIRMS' R&D/SALES RATIOS IN 1978 -- CANADIAN- VS. FOREIGN-CONTROLLED FIRMS

Industry	R&D/Sales Ratios Average	Median
	-- (%) --	
Telecommunications Equipment and Components:		
Canadian-Controlled Firms (31)	12.8	10.0
Foreign-Controlled Firms (25)	5.6	3.2
Electrical Industrial Equipment:		
Canadian-Controlled Firms (19)	5.0	2.6
Foreign-Controlled Firms (22)	1.7	1.0
Plastics Compounds and Synthetic Resins:		
Canadian-Controlled Firms (9)	1.5	1.0
Foreign-Controlled Firms (8)	1.0	0.4
Smelting and Refining:		
Canadian-Controlled Firms (3)	3.0	0.7
Foreign-Controlled Firms (7)	0.6	0.4
Crude Petroleum Production:		
Canadian-Controlled Firms (4)	0.3	0
Foreign-Controlled Firms (6)	3.6	6.4
All Canadian-Controlled Firms (66)	8.5	4.0
All Foreign-Controlled Firms (68)	3.1	1.6

Because firm size has such a strong influence on these ratios, we also present the R&D/sales ratios of firms by size of firm for Canadian- and foreign-controlled firms.

Table 13

AVERAGE OF RATIOS OF R&D TO SALES IN 1978 --
CANADIAN- VS. FOREIGN-CONTROLLED FIRMS BY SIZE OF FIRM

No. of Employees in the Field	Canadian-Controlled Firms No.	Canadian-Controlled Firms R&D/Sales Ratio	Foreign-Controlled Firms No.	Foreign-Controlled Firms R&D/Sales Ratio
		(Mean %)		(Mean %)
50 or less	34	11.2	13	3.3
100 or less	45	10.1	23	4.3
200 or less	54	9.1	38	3.7
500 or less	60	8.4	54	3.4
More than 500	5	10.3	14	2.0

When adjusted on the basis of firm size, the tendency for foreign-controlled firms to spend less than Canadian-controlled firms on R&D per sales dollar persists. On the basis of our findings in this chapter respecting innovation expenditure profiles, it seems likely that the lower spending on R&D per sales dollar arises from the greater tendency of foreign firms to import technology (primarily from parent or affiliated firms abroad) and for the innovations resulting from imported technology to require significantly less research and development spending.

R&D to sales ratios provide one measure of R&D effort. Two other indicators of the availability of R&D resources within firms are the numbers of scientists and engineers employed and the level of R&D spending per scientist and engineer engaged in R&D work. A measure of R&D effort of firms is the level of R&D spending per employee in the field which can be termed the R&D intensity of the firm. This latter measure comes closer to the R&D to sales measures discussed above. The following sections examine these measures by industry and firm characteristics.

Employment of Scientists and Engineers and R&D Spending

For all industries, the mean number of scientists and engineers employed by reporting firms was 12 and the median number was 4 (Table 14).

Table 14

EMPLOYMENT OF SCIENTISTS AND ENGINEERS, BY ORIGIN OF CONTROL AND INDUSTRY, 1978

Industry	Total Number of Scientists and Engineers		
	No. of Firms	Mean	Median
		(No.)	(No.)
All Industries:	149	12	4
Canadian-Controlled Firms	70	9	3
Foreign-Controlled Firms	79	14	6
Telecommunications Equipment and Components:	59	12	6
Canadian-Controlled Firms	33	7	5
Foreign-Controlled Firms	26	17	7
Electrical Industrial Equipment:	46	6	2
Canadian-Controlled Firms	21	6	2
Foreign-Controlled Firms	25	7	2
Plastics Compounds and Synthetic Resins:	20	8	6
Canadian-Controlled Firms	9	7	5
Foreign-Controlled Firms	11	9	7
Smelting and Refining:	10	18	15
Canadian-Controlled Firms	2	10	3
Foreign-Controlled Firms	8	20	15
Crude Petroleum Production:	13	18	3
Canadian-Controlled Firms	4	1	0
Foreign-Controlled Firms	9	26	11

The following discussion will focus on the median values. The average numbers of scientists and engineers employed in firms in R&D will reflect the size of firms, the technological opportunities facing the firms and the technology itself. Smelting and refining and the foreign-controlled sector of the crude petroleum production industry employ relatively large numbers of scientists and engineers. The smaller Canadian-controlled firms in crude petroleum production conduct little R&D themselves. To undertake R&D in these industries requires relatively large numbers of R&D workers. Average number of R&D workers in telecommunications equipment and components and plastics compounds and synthetic resins are both above the average for all industries, while the electrical industrial equipment average is below that for all industries.

There are differences in the average number of scientists and engineers employed by Canadian- and foreign-controlled firms. In general, Canadian-controlled firms employ smaller numbers of R&D workers, except in electrical industrial equipment where average numbers are low for both types of firms. However, this difference is clearly size-related. Table 15 sets out these averages for the two types of firms by size of firm. When adjusted for firm size, the average number of scientists and engineers employed in R&D in Canadian-controlled firms is higher. The difference is most marked for the smallest firms, no doubt reflecting the tendency of the very small foreign-controlled firms to rely on parent and affiliate firms' R&D resources.

Table 15

EMPLOYMENT OF SCIENTISTS AND ENGINEERS, BY SIZE OF FIRM AND ORIGIN OF CONTROL

No. of Employees in the Field	All Firms			Canadian-Controlled			Foreign-Controlled		
	No. of Firms	Mean	Median	No. of Firms	Mean	Median	No. of Firms	Mean	Median
		(No.)	(No.)		(No.)	(No.)		(No.)	(No.)
0-50	54	3	2	38	3	3	16	3	1
51-100	23	7	6	12	7	6	11	8	5
101-200	27	11	5	9	8	5	18	13	3
200-500	24	16	6	6	20	6	18	15	5
More than 500	19	39	20	3	81	21	16	30	19

For all industries, the median level of R&D spending per scientist and engineer is slightly higher for foreign-controlled firms, but in two industries, plastics compounds and synthetic resins, and smelting and refining, the ratios for Canadian-controlled firms are higher (Table 16). The two Canadian-controlled firms in smelting and refining for which we have the required

Table 16

R&D EXPENDITURES PER R&D SCIENTIST AND ENGINEER AND PER EMPLOYEE IN THE FIELD, BY ORIGIN OF CONTROL AND INDUSTRY, 1978

Industry	R&D Expenditures Per R&D Employee			R&D Expenditures Per Employee in Field		
	No. of Firms	Mean	Median	No. of Firms	Mean	Median
		($)	($)		($)	($)
All Industries:	119	59,537	30,000	136	4,572	1,667
Canadian-Controlled Firms	58	37,909	26,647	66	4,504	2,000
Foreign-Controlled Firms	61	80,102	33,917	70	4,635	1,053
Telecommunications Equipment and Components:	53	38,170	27,083	56	5,094	2,800
Canadian-Controlled Firms	30	28,963	26,000	31	6,385	3,818
Foreign-Controlled Firms	23	50,179	30,881	25	3,493	1,894
Electrical Industrial Equipment:	34	50,574	25,000	42	1,422	612
Canadian-Controlled Firms	16	24,641	20,000	19	1,997	1,031
Foreign-Controlled Firms	18	73,625	30,000	23	946	446
Plastics Compounds and Synthetic Resins:	15	41,081	31,000	15	2,269	1,392
Canadian-Controlled Firms	7	33,388	31,667	7	1,740	1,549
Foreign-Controlled Firms	8	47,812	25,000	8	2,732	991
Smelting and Refining:	9	81,191	38,775	11	3,997	958
Canadian-Controlled Firms	2	205,932	71,230	4	9,235	862
Foreign-Controlled Firms	7	45,551	33,775	7	1,004	949
Crude Petroleum Production:	7	279,358	205,333	11	17,407	3,517
Canadian-Controlled Firms	2	125,000	0	4	1,250	0
Foreign-Controlled Firms	5	341,101	263,667	7	26,639	6,857

information are both relatively large firms. Clearly the size of the firm is again affecting these ratios. When we control for size of firm, we find that R&D spending per R&D worker is slightly greater for smaller foreign-controlled firms, and slightly less for medium-sized firms when compared to Canadian-controlled firms (Table 17). However, average R&D spending per employee for the very large foreign-controlled firms is considerably greater than for the few Canadian-controlled firms in this category. Even so, these ratios do not show great variability (with a few exceptions) among types of firms within industries or by size of firm. The significant variation is among industries. This indicates that, in general, to do research in a specific area of technology and apply the technology to the development of innovations in that area requires a fairly predictable level of R&D resources per R&D worker, but the level of resources available per worker does increase somewhat with the size of firms.

Table 17

R&D EXPENDITURES PER R&D SCIENTIST AND ENGINEER
BY SIZE OF FIRM AND ORIGIN OF CONTROL, ALL INDUSTRIES, 1978

No. of Employees in the Field	All Firms			Canadian-Controlled			Foreign-Controlled		
	No. of Firms	Mean	Median	No. of Firms	Mean	Median	No. of Firms	Mean	Median
		($)	($)		($)	($)		($)	($)
0-50	40	50,022	22,545	30	34,615	20,000	9	104,716	25,000
51-100	20	46,861	25,000	10	48,793	21,667	10	44,928	25,000
101-200	19	47,316	30,000	7	39,914	32,500	12	54,800	26,000
201-500	22	65,628	34,833	6	32,368	34,833	16	78,101	34,500
More than 500	18	94,916	53,903	3	38,333	32,500	14	113,377	59,417

We next examine the R&D intensity of the industries and firms in terms of R&D spending per employee in the field (see Table 16 above). Overall, R&D spending per employee is slightly higher in the Canadian-controlled firms. This parallels our findings in respect of R&D to sales ratios. This result holds at the industry level for 3 industries but not in the case of smelting and refining firms (where the intensity ratio of the foreign-controlled firms is slightly higher) and crude petroleum production (where Canadian-controlled firms undertake little R&D). Thus when we measure R&D intensity in terms of R&D spending per employee (as opposed to R&D to sales ratios), the tendency for Canadian-controlled firms to be more R&D-intensive is not as pervasive at the industry level. This reflects the fact discussed above in respect of R&D to sales ratios, that Canadian-controlled firms have relatively lower sales per employee than foreign-controlled firms.

Furthermore, when we compare the R&D spending per employee ratios ratios for small and large firms, we find the small Canadian-controlled firms are considerably more R&D-intensive than their foreign-controlled counterparts, but that the larger foreign-controlled firms are more R&D-intensive than larger Canadian-controlled firms.

Table 18

R&D EXPENDITURES PER EMPLOYEE IN THE FIELD
BY SIZE OF FIRM AND ORIGIN OF CONTROL, ALL INDUSTRIES, 1978

No. of Employees in the Field	All Firms			Canadian-Controlled			Foreign-Controlled		
	No. of Firms	Mean ($)	Median ($)	No. of Firms	Mean ($)	Median ($)	No. of Firms	Mean ($)	Median ($)
0-50	46	8,665	2,175	33	6,889	3,485	13	13,770	908
51-100	21	2,945	2,479	11	2,901	2,316	10	2,993	2,458
101-200	24	1,991	1,167	9	2,111	1,700	15	1,919	711
201-500	26	2,654	845	8	1,030	612	18	3,376	1,111
More than 500	19	1,853	862	5	2,163	458	14	1,853	991

It appears, therefore, that Canadian-controlled firms of all sizes in 1978 have higher R&D/sales ratios and employ greater numbers of scientists and engineers than their foreign-controlled counterparts. However, very small Canadian-controlled firms are much more R&D-intensive than very small foreign-controlled firms, while the reverse is true of large firms when the R&D per employee measure is used. Also, the smaller and the very large foreign-controlled firms have higher levels of R&D spending per scientist and engineer than do comparably sized Canadian-controlled firms.

These results point to the conclusion that Canadian-controlled firms generally show a relatively higher R&D intensity but are smaller and their R&D personnel are less well endowed with resources for carrying out R&D activities than their foreign-controlled counterparts. It should be pointed out that the evidence on R&D intensity of large foreign-controlled firms is somewhat mixed. R&D sales ratios associated with these firms are small relative to large Canadian-controlled firms, but when measured on the basis of employment size, the larger foreign-controlled firms tend to be more R&D-intensive than their Canadian-controlled counterparts.

Summary

Total expenditures on 234 reported innovations for which expenditure profiles were provided amounted to $631.2 million: $131.7 million for 169 product innovations and $499.5 million for 65 process innovations.

Innovation is an expensive proposition -- even the median expenditures of firms on their major product and process innovations were $213,000 and $533,000, respectively, while mean expenditures were $779,000 for product innovations and $7.7 million for process innovations.

Process innovations are thus significantly more expensive to develop and to introduce.

Average expenditure ratios per innovation for product and process innovations by stage of process are as follows:

	Product Innovations Mean %	Process Innovations Mean %
Basic Research	7	4
Applied Research	13	14
Development	43	30
Manufacturing Start-Up	28	50
Marketing Start-Up	10	2

Developmental and manufacturing start-up expenditures are, on average, the major components of expenditures on the reported innovations -- with developmental costs being predominant for product innovations and manufacturing start-up costs dominating in the case of process innovations.

There is great variability in these expenditure profiles by stage of process among the five industries, reflecting differences in the nature of the innovations being developed.

Average spending profiles by stage of process are very sensitive to the size of the innovation. In general, the larger (more costly) the innovation, the greater the relative importance of manufacturing start-up costs and the lesser the importance of both research and developmental costs.

The average spending profiles of innovations based on imported technology have relatively very low basic research components, lower applied research components, and slightly lower developmental components.

The importation of technology clearly substitutes for research (particularly basic or fundamental research) and to a slight degree for developmental work on the part of the firms obtaining the technology externally. In many cases, in the absence of the technology imports, the innovation would not have been introduced into the firm and in the other cases the development of the innovation would have been slower and much more costly.

The majority of reported innovations involved no basic research and a large proportion no applied research. As expected, the proportion of innovations involving no research was significantly higher for innovations based on imported technology.

Original (world-first) and imitative innovations have rather similar expenditure profiles, the difference being explained by the skewed profiles of innovations based on imported technology which accounted for a larger proportion of the imitative innovations.

The average expenditure profiles of foreign-controlled firms have relatively smaller research and development components than those of Canadian-controlled firms (see Chapter V for a detailed examination of the differences).

R&D to sales ratios of firms vary significantly among industries -- averaging 9.6 per cent in telecommunications equipment, 3.2 per cent in electrical industrial equipment, 1.3 per cent in plastics compounds and synthetic resins, 1.3 per cent in smelting and refining, and 2.3 per cent in crude petroleum production.

R&D to sales ratios vary markedly with the size of the firm -- falling continuously as size increases. Smaller firms, particularly in the higher technology industries are found to spend significantly more on R&D per dollar of sales.

In general, the R&D to sales ratios of foreign-controlled firms are lower than those of Canadian-controlled firms, and this is also true at the industry level, except in the case of crude petroleum production firms where it is mainly the large firms (most of which are foreign-controlled) doing extensive R&D work.

When we control for size of firm, we still find that foreign-controlled firms have lower R&D to sales ratios than Canadian-controlled firms. This primarily reflects the fact that foreign-controlled firms have general access to the R&D results of parent and affiliated firms abroad and often do not attempt to duplicate this work in Canada.

Small Canadian-controlled firms also show greater R&D intensity (R&D spending per employee in the field) than small foreign-controlled firms. However, for large firms, R&D intensity is greater in foreign- than in Canadian-controlled firms. Differences in R&D/sales ratios and R&D-intensity as to firm size and control characteristics arise out of the generally lower levels of sales per employee for Canadian-controlled firms.

When adjusted for size of firm, the average number of R&D scientists and engineers employed in Canadian-controlled firms exceeds that for foreign-controlled firms.

The level of R&D spending per R&D scientist and engineer is slightly higher for small foreign-controlled firms and considerably greater for large foreign-controlled firms when compared to comparably sized Canadian-controlled firms. However, levels of R&D spending per R&D scientist and engineer are slightly greater for medium-sized Canadian-controlled firms compared to medium-sized foreign-controlled firms. There is wide inter-industry variation in this measure, reflecting industry-specific technology characteristics and consequent requirements for R&D spending.

Canadian-controlled firms generally show a relatively higher R&D intensity with reference to measures based on R&D spending in Canada, but are less well-endowed with resources for carrying out R&D activities than their foreign-controlled counterparts.

Chapter IV

SOURCES OF TECHNOLOGY FOR CANADIAN INNOVATIONS

Primary Sources of Technology: Internal vs. External Sources

An alternative to developing the technology for prospective innovations in-house is to obtain it from outside the firm. Possible external sources include a parent firm, an affiliate or subsidiary of the parent, customer or supplier firms, outside consultants including consulting firms and individuals, independent inventors, and institutions such as government research centres and universities. The primary source of the technology was determined for all of the 283 innovations.

The technology for 187 of the innovations (66 per cent of all reported innovations) was primarily developed in-house by the innovating firm (Table 1). The technology for 77 of the innovations (27 per cent of all innovations) was primarily acquired from outside the firm. In addition, there were 19 innovations (7 per cent) where both externally acquired technology and technology developed in-house were of equal importance. These latter innovations tended to be very large technologically sophisticated innovations. Thus, for major innovations we find a heavy reliance on technology developed in-house exclusively or developed in-house in conjunction with externally acquired technology. Exclusive reliance on technology with a primary source outside the firm is not as common as we would have expected. There may be a bias on the part of responding firms towards reporting innovations based on technologies developed primarily with internal skills. However, we should point out that in Chapter IX we find the measured rate of utilization of externally acquired technology declines in the 1970s as compared to the 1960s, with the result that in the 1970s external technology was the sole primary source of only 20 per cent of reported innovations.

Table 1

PRIMARY SOURCE OF TECHNOLOGY, PRODUCTS AND PROCESSES, BY CONTROL, ALL INDUSTRIES

Type	Technology Acquired Externally		Technology Developed In-House		Combined External and In-House	
	No.	%	No.	%	No.	%
Canadian-Controlled Innovations:	14	12	99	81	8	7
Product	8	8	84	88	4	4
Process	6	24	15	60	4	16
Foreign-Controlled Innovations:	63	39	88	54	11	7
Product	40	38	64	61	1	1
Process	23	40	24	42	10	18
All Innovations:	77	27	187	66	19	7
Product	48	24	148	74	5	2
Process	29	35	39	48	14	17

Foreign-controlled firms in Canada are involved to a significant degree in the development of new technologies via in-house R&D effort, although the reliance upon in-house R&D is considerably less than for Canadian-controlled firms. Only 12 per cent of the innovations adopted by Canadian-controlled firms depend exclusively upon an external source of technology, whereas 39 per cent of the innovations of foreign-controlled firms do so (Table 1).

Although process innovations form 29 per cent of all reported innovations, they form 45 per cent of all innovations utilizing external sources and combinations of external plus internal technology sources. Canadian-controlled firms, and to an even greater extent foreign-controlled firms, show a tendency to acquire a relatively large proportion of their process technology from external sources. For both products and processes, the propensity to develop technology in-house is greater for Canadian- than for foreign-controlled firms.

The relative reliance upon the three sources of technology varies across industries, with the two product-oriented industries -- telecommunications equipment and components and electrical industrial equipment -- utilizing technologies developed in-house to a greater extent than the three process-oriented industries -- plastics compounds and synthetic resins, smelting and refining, and electrical industrial equipment (Table 2). Even within each industry, the Canadian-controlled firms show a relatively greater reliance upon technologies developed in-house than do foreign-controlled firms, the corollary being that foreign-controlled firms more easily utilize external sources of technology.

Table 2

PRIMARY SOURCE OF INNOVATIONS' TECHNOLOGY, BY CONTROL OF FIRM AND INDUSTRY

Industry	Technology Acquired Externally		Technology Developed In-House		Combined External and In-House	
	No.	%	No.	%	No.	%
1. Telecommunications Equipment and Components	21	19.4	81	75.0	6	5.6
Canadian-Controlled	5	8.5	49	83.1	5	8.5
Foreign-Controlled	16	32.7	32	65.3	1	2.0
2. Electrical Industrial Equipment	18	26.5	47	69.1	3	4.4
Canadian-Controlled	5	17.2	23	79.3	1	3.5
Foreign-Controlled	13	33.3	24	61.5	2	5.1
3. Plastics Compounds and Synthetic Resins	13	32.5	25	62.5	2	5.0
Canadian-Controlled	0	0.0	14	93.3	1	6.7
Foreign-Controlled	13	52.0	11	44.0	1	4.0
4. Smelting and Refining	9	27.3	20	60.6	4	12.1
Canadian-Controlled	2	20.0	7	70.0	1	10.0
Foreign-Controlled	7	30.4	13	56.5	3	13.1
5. Crude Petroleum Production	16	53.3	10	33.3	4	13.3
Canadian-Controlled	2	40.0	3	60.0	0	0.0
Foreign-Controlled	14	56.0	7	28.0	4	16.0

In summary, we find that for only 77 innovations (27 per cent of all innovations) was the sole primary source of the technology external to the firm. Furthermore, for 48 of these innovations, the external source was a parent or affiliate firm. Other external primary technology sources were very sparse, being utilized in only 10 per cent of all reported innovations. Innovations where the primary source of the technology was a combination of in-house developments and externally acquired technology are also rather rare and represent large technologically sophisticated innovations. There were only 19 of these and 5 involved intracorporate MNE transfers.

The heavier utilization of internally developed technology by Canadian-controlled firms holds not only across industries, but also across firm size categories (Table 3). In the case of innovations associated with foreign-controlled firms, dependence upon external sources of technology at first decreases sharply with firm size, but

Table 3

PRIMARY SOURCE OF INNOVATION'S TECHNOLOGY
BY CONTROL OF FIRM AND SIZE,
ALL INDUSTRIES

Industry	Technology Acquired Externally		Technology Developed In-House		Combined External and In-House	
	No.	%	No.	%	No.	%
1. 0-50 employees						
Canadian-controlled	8	15.7	41	80.4	2	3.9
Foreign-controlled	17	65.4	7	26.9	2	7.7
2. 51-100 employees						
Canadian-controlled	1	5.3	17	89.5	1	5.3
Foreign-controlled	5	26.3	13	68.4	1	5.3
3. 101-200 employees						
Canadian-controlled	1	6.7	12	80.0	2	13.3
Foreign-controlled	6	20.0	21	70.0	3	10.0
4. 201-500 employees						
Canadian-controlled	2	11.1	14	77.8	2	11.1
Foreign-controlled	16	41.0	22	56.4	1	2.6
5. More than 500 employees						
Canadian-controlled	2	16.7	9	75.0	1	8.3
Foreign-controlled	16	38.1	24	57.1	2	4.8

for firms with more than 200 employees, reliance on external technology increases again. Canadian-controlled firms of all sizes depend to a much smaller extent on external sources of technology, but the very smallest and very largest of these firms show the greatest relative utilization of external technology. The heavy utilization of externally acquired technology by the very small foreign-controlled firms stands out strongly.

The relative importance of the three primary sources of technology by firm size across industries shows very large differences (Table 4). Looking first at small firms only, it is the telecommunications equipment and components, electrical industrial equipment, and the plastics compounds and synthetic resins industries which contain small firms which most heavily utilize in-house R&D for their technologies. Although the extent of utilization of external sources of technology is very great across all firm size categories in the crude petroleum production sector, it is most marked among small crude petroleum producers.

Source of technology and firm size characteristics also show large contrasts within each industry. Large firms within the electrical industrial equipment, smelting and refining and crude petroleum production industries actually depend more heavily upon in-house R&D for developing their new technologies than do small firms within these industries. Therefore, the finding reached above that small firms utilize in-house R&D more than do large firms is largely an industry-specific phenomenon: it is the large number of innovations produced by small telecommunications equipment and component firms via in-house R&D which causes this trend to emerge. In fact, there is a relatively large number of small firms in the smelting and refining and crude petroleum industries utilizing external sources of technology.

Table 4

SOURCE OF TECHNOLOGY, BY SIZE OF FIRM, BY INDUSTRY

Source of Technology	Number of Employees in Field: 0-50		51-100		101-200		201-500		More than 500	
	No.	%	No.	%	No.	%	No.	%	No.	%
1. Telecommunications Equipment and Components										
External Source	11	28.2	0	0.0	3	13.6	4	30.8	3	30.0
Internal R&D	26	66.7	20	100.0	18	81.8	7	53.8	6	60.0
Both	2	5.1	0	0.0	1	4.6	2	15.4	1	10.0
Total	39	100.0	20	100.0	22	100.0	13	100.0	10	100.0
2. Electrical Industrial Equipment										
External Source	7	33.3	3	50.0	3	27.3	4	25.0	1	9.1
Internal R&D	13	61.9	3	50.0	7	63.6	12	75.0	10	90.9
Both	1	4.8	0	0.0	1	9.1	0	0.0	0	0.0
Total	21	100.0	6	100.0	11	100.0	11	100.0	11	100.0
3. Plastics Compounds and Synthetic Resins										
External Source	1	16.7	3	37.5	1	11.1	4	36.4	2	50.0
Internal R&D	5	83.3	4	50.0	7	77.8	7	63.6	2	50.0
Both	0	0.0	1	12.5	1	11.1	0	0.0	0	0.0
Total	6	100.0	8	100.0	9	100.0	11	100.0	4	100.0
4. Smelting and Refining										
External Source	2	40.0	0	0.0	0	0.0	3	23.1	4	30.8
Internal R&D	2	40.0	0	0.0	0	0.0	9	69.2	8	61.5
Both	1	20.0	1	100.0	0	0.0	1	7.7	1	7.7
Total	5	100.0	1	100.0	0	0.0	13	100.0	13	100.0
5. Crude Petroleum Production										
External Source	4	80.0	0	0.0	0	0.0	3	75.5	8	61.5
Internal R&D	1	20.0	3	100.0	1	33.3	1	25.0	4	30.8
Both	0	0.0	0	0.0	2	66.7	0	0.0	1	7.7
Total	5	100.0	3	100.0	3	100.0	4	100.0	13	100.0

The industry exhibiting the most unique characteristics in terms of sources of technology is the electrical industrial equipment industry, which contains small firms depending upon internal sources of technology to about the same extent as do other industries but which also contains large firms which use external sources of technology much less than do firms in any other industry. This partially reflects the special nature of this industry in that one important reason for the establishment of plants in Canada is the fact that equipment specifications and standards differ internationally. Since for many types of electrical industrial equipment the market in Canada is rather specialized, the extent to which firms operating in Canada must internally develop technologies is greater than for other industries.

The Source Countries for Externally Acquired Technologies

In total, there are 96 cases in which the primary technology for the innovation was in whole or in part acquired from outside the firm. In only 14 of these transfers was the external source based in Canada. In other words, technology transfers consist predominantly of imported technologies. Firms based in the United States supplied 66 per cent of all externally acquired innovations with the balance being supplied by firms primarily in Western Europe (Table 5). The United States is the predominant source of both product and process technologies, supplying 72 per cent and 58 per cent, respectively. The only other single source country of any importance at all is Canada. As will be seen further below, the few Canadian sources consist primarily of consultants. Thus when firms in Canada do acquire technology externally, it is mostly acquired from abroad, primarily from the United States.

Table 5

SOURCE COUNTRY OF TRANSFERRED TECHNOLOGIES, BY ORIGIN OF CONTROL OF RECIPIENT FIRMS

Country	All Innovations Based on Externally Acquired Technology		Canadian-Controlled Innovations		Foreign-Controlled Innovations	
	No.	%	No.	%	No.	%
Canada	14	14.6	6	27.4	8	10.8
United States	63	65.6	10	45.5	53	71.6
United Kingdom	4	4.3	1	4.5	3	4.1
West Germany	3	3.1	2	9.1	1	1.4
France	2	2.2	0	0.0	2	2.6
Italy	1	1.0	1	4.5	0	0.0
Scandinavia	3	3.1	0	0.0	3	4.1
Switzerland	1	1.0	0	0.0	1	1.4
South Africa	1	1.0	1	4.5	0	0.0
Australia	1	1.0	0	0.0	1	1.4
Other	3	3.1	1	4.5	2	2.6
Total	96	100.0	22	100.0	74	100.0

Specific Primary Sources of Externally Acquired Technology

We can also examine the specific external sources of the technologies for our major innovations in greater detail (see Table 6). For the 96 innovations where the technology was primarily based in whole (77) or in part (19) on externally acquired technology, 40 innovations drew on a parent firm and 13 more drew on affiliated firms for the technology. Thus 53 of the 96 innovations (55 per cent) were based on technology obtained via intracorporate (MNE) transfers. Only 43 innovations drew on other external sources and these are broken down in more specific terms in Table 6. Suppliers and consultants (24 cases) were the most important external sources other than intracorporate sources. Joint ventures were a primary source of technology in only 9 cases. Thus it is quite clear that innovations based on arm's-length sources of external technology have not been important relative to total reported innovations (representing only 15 per cent). Innovations based on intracorporate transfers represented 19 per cent of total reported innovations. With a single exception, intracorporate transfers were to foreign-controlled firms and in the case of the single intracorporate transfer to a Canadian-controlled firm, the transfer was from an affiliate located in the United States. Thus all intracorporate transfers are, in fact, MNE transfers.

Table 6

EXTERNAL SOURCES OF TECHNOLOGY FOR THE INNOVATION
BY CONTROL OF FIRM, ALL INDUSTRIES

External Source	All Innovations		Canadian-Controlled Innovations		Foreign-Controlled Innovations	
	No.	%	No.	%	No.	%
Intracorporate						
From your parent	40	41.7	1	4.5	39	52.7
From an affiliate of your parent	13	13.5	0	0.0	13	17.6
Arm's-Length						
From a customer	5	5.2	1	4.5	4	5.4
From a supplier	13	13.5	7	31.8	6	8.1
Via joint venture with an unaffiliated firm	9	9.4	5	2.8	4	5.4
From a Consultant	11	11.5	5	2.8	6	8.1
Other	5	5.2	3	13.6	2	2.7
Total	96	100.0	22	100.0	74	100.0

In Table 6 we distinguish arm's-length technology transfers and intracorporate MNE transfers. Technology transfers to Canadian-controlled firms were all made on an arm's-length basis except for the one transfer referred to above. However, 30 per cent of the transfers to foreign-controlled firms were also made on an arm's-length basis. Technology transfers to Canadian-controlled firms are primarily from a supplier or consultant or via joint venture. Only in the case of transfers from a customer do foreign-controlled firms show a greater proportionate use of particular arm's-length source of technology than do Canadian-controlled firms. This is because of the dominance of intracorporate sources of technology for foreign-controlled firms, which reduces the relative frequency of use of all other sources.

Of the 43 transfers made on an arm's-length basis, firms situated in Canada were the technology suppliers in 12 cases, while U.S.-situated firms were the source country for the technology in 19 cases, the remaining 11 sources being other foreign countries. Of the few Canadian-based technology sources being utilized, consultants were the predominant specific source, providing the technology in 8 of the 12 cases of arm's-length transfers effected within Canada.

When firm size and control are examined in conjunction with the nature of the external sources of technology, the differing forces affecting Canadian- and foreign-controlled firms becomes apparent. Foreign-controlled firms utilize external sources for technologies more often because they have access to parent companies and affiliates of parents based abroad, mostly in the United States. In contrast, Canadian-controlled firms rely little upon external sources of technology and, when they do, the relationship is arm's-length. It is apparent, then, that foreign-controlled firms are drawing upon R&D performed by their parent and affiliated companies, particularly research (see Chapter III). Canadian-controlled firms, on the other hand, do not normally have such intracorporate ties and are forced to depend heavily on R&D resources internal to the firm (supplementing this to a small extent with arm's-length technology transfers). Basically all of the differences across control in terms of external sources of technology arise from MNE transfers, where 52 occur with foreign-controlled firms and only one with a Canadian-controlled firm.

These very striking differences lead to questions regarding the nature of the transfer agreements themselves. Do transfers to Canadian-controlled firms differ from those of foreign-controlled firms? Do arm's-length transfers differ from transfers made within MNEs? Are Canadian-controlled firms treated differently on an arm's-length basis than are foreign-controlled firms? Before answering these questions, it is first necessary to examine the means used to effect technology transfers.

Mechanisms for Technology Transfers

The technology transfers to firms in Canada have been separated into formal licensing agreements and "other transfer agreements". As will be seen further below, these agreements can be one-time transfers or continuous (including access to future technology developed by the supplier of the technology), and they involve cross-licenses in a few cases. Table 7 compares the frequency of licensing agreements as between intracorporate MNE technology transfers and arm's-length transfers.

Table 7

MECHANISMS FOR TECHNOLOGY TRANSFER,
MNE vs. ARM'S-LENGTH

Transfer Mechanism	MNE No.	MNE %	Arm's-Length No.	Arm's-Length %
Licenses	10	19	14	44
Other transfer agreements	43	81	18	56
All agreements	53	100	32	100

Note: In the 11 cases where consultants were used, information regarding transfer agreements was not obtained.

A very large proportion of the technology transfers within MNEs are effected via "other transfer agreements" rather than by formal licenses. Most MNEs allow their subsidiaries full access to the R&D resources available within the MNE. In return for this access to R&D facilities, subsidiaries generally pay an annual fee to the parent company which is not necessarily specific to the technology transferred to the subsidiary (see the discussion of this issue in Chapter V). Much less frequently is the parent-subsidiary relationship formalized via a licensing agreement. For transfers on an arm's-lenth basis, formal licensing agreements become relatively more important, but surprisingly are still less important than "other transfer agreements". These "other transfer agreements" on an arm's-length basis are in most cases one-time acquisitions of technology*, and in this respect differ radically from the non-licensing transfer agreements within MNEs which are almost all continuous and represent very complete technology transfers from parents to subsidiaries (or between subsidiaries). It turns out that licensing agreements have not been an important mechanism for transferring technologies to firms developing their major innovations; even in the case of arm's-length transfers, most of the transfers have not been licensing agreements.

The relative use of licensing agreements in technology transfers can also be examined for Canadian- and foreign-controlled firms. This comparison will, of course, be strongly influenced by the dominance of the intracorporate MNE transfers in the transfers to foreign-controlled firms in Canada. The population of technology transfers in this comparison and in the balance of this chapter changes slightly. Of the 96 transfers, 11 were technology acquisitions from consulting firms and detailed information on these transfers was not obtained. However, we did obtain information on 11 additional technology transfer agreements where the technology provided was ancillary or secondary technology (i.e., it was not a prime source). These transfers are included in the analysis.

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* For example, only 36 per cent of the arm's-length licenses are one-time technology transfers, whereas 65 per cent of the "other" arm's-length transfers are one-time transfers of technology.

Table 8

MECHANISMS FOR TECHNOLOGY TRANSFER, BY CONTROL

	Foreign-Controlled Innovations		Canadian-Controlled Innovations	
	No.	%	No.	%
Licenses	17	22	12	60
Other transfer agreements	59	78	8	40
All agreements*	76	100	20	100

*This table does not include the 11 transfers involving consultants, but does include 11 secondary license or other transfer agreements which were associated with innovations in which internal R&D was the primary source of technology.

In terms of the origin of control of the firms in Canada acquiring technology, 21 per cent of these transfers were to Canadian-controlled firms and 79 per cent to foreign-controlled firms. Of the 20 transfers to Canadian-controlled firms, the majority (12) were licensing agreements (60 per cent) and 8 were other transfer agreements. In contrast, only 22 per cent of the transfers to foreign-controlled firms were via license because of the dominance of the intracorporate MNE transfer, most of which are not under formal licenses. Only 6 (38 per cent) of the 16 arm's-length transfers to foreign-controlled firms were effected via license, the remainder being technology purchase agreements similar to those of Canadian-controlled firms (Table 9). Thus, when we compare only arm's-length transfers between Canadian- and foreign-controlled firms, the difference in frequency of use of licensing diminishes, but Canadian-controlled firms still show a tendency to rely on formal licenses to a greater extent than foreign-controlled firms.

Table 9

MECHANISMS FOR TECHNOLOGY TRANSFER
ON AN ARM'S-LENGTH BASIS,
CANADIAN- AND FOREIGN-CONTROLLED FIRMS

Control Characteristics	License Agreement		Other Transfer Agreement		Total	
	No.	%	No.	%	No.	%
Canadian-Controlled Innovations	8	50	8	50	16	100
Foreign-Controlled Innovations	6	38	10	62	16	100

The Nature of the Technology Transfer Agreements

In the survey, we collected information on some of the characteristics of the technology transfer agreements and on the restrictions contained in these agreements. Are the agreements one-time transfer agreements or continuous? Do they involve cross-licensees? Are they in writing? What sort of rights do they contain, and are these rights exclusive? Do the agreements contain territorial restrictions or restrictions on sources of inputs? These aspects of the agreements are analysed for Canadian- and foreign-controlled firms and for intracorporate MNE and arm's-length transfers.

As can be seen in Table 10, 73 per cent of the agreements provided for a continuous transfer of technology (i.e., as the supplier develops improved technologies in the area of the transfer it is made available to the recipient firm under the terms of the agreement). As expected, 80 per cent of the agreements of foreign-controlled firms are continuous, reflecting the predominance of intracorporate agreements, but only 45 per cent of the agreements of Canadian-controlled firms provide for continuous technology transfers. The agreements were in writing in 67 per cent of the cases, but this was more common in respect of the agreements involving Canadian-controlled firms. Eight of the cross-licenses were agreements involving foreign-controlled firms.

Table 10

NATURE OF TECHNOLOGY TRANSFER AGREEMENT, BY CONTROL

	TOTAL			CANADIAN-CONTROLLED			FOREIGN-CONTROLLED		
Conditions of Agreement	No. of Respondents	No. Indicating "Yes"	% of Total Respondents Indicating "Yes"	No. of Respondents	No. Indicating "Yes"	% of Total Respondents Indicating "Yes"	No. of Respondents	No. Indicating "Yes"	% of Total Respondents Indicating "Yes"
	No.	No.	%	No.	No.	%	No.	No.	%
Continuous	95	69	72.6	20	9	45.0	75	60	80.0
One-time	95	26	27.4	20	11	55.0	75	15	20.0
Cross licence	88	10	11.4	18	2	11.1	70	8	11.4
Written	90	60	66.7	19	16	84.2	71	44	62.0
Gives right to manufacture	74	55	74.3	18	14	77.8	56	41	73.2
Gives right to sell	78	55	70.5	18	15	83.3	60	40	66.7
Gives right to use in manufacture	61	51	83.6	13	12	92.3	48	39	81.2
Gives right to use of trademark	66	35	53.0	16	8	50.0	50	27	54.0
Specifies territory of manufacture	83	35	42.2	19	6	31.6	64	29	45.3
Specifies territory of sales	83	29	34.9	19	6	31.6	64	23	35.9
Gives exclusive right to manufacture	70	32	45.7	13	7	53.8	57	25	43.9
Gives exclusive right to sell	70	30	42.9	14	7	50.0	56	23	41.1
Specifies input sources	75	2	2.7	16	0	0.0	59	2	3.4
Total No. of cases	95			20			75		

In respect of the characteristics of the transfer agreements, over 70 per cent of the agreements provided specific rights to manufacture or sell products, the percentage being slightly higher for Canadian-controlled firms. The right to use the technology in production processes was specified even more often, and again the percentage was higher for agreements with Canadian-controlled firms. Both the right to manufacture and the right to use in manufacture were provided for in 34 cases (35 per cent of the agreements), indicating a product and process technology package was being provided. In only 20 cases did the agreement specify only the right to manufacture with no right to use of technology in the manufacturing of the products, and in only 16 cases was the right to use a technology specified in the absence of the right to manufacture a specific product. Therefore, the vast majority of technology transfers (70 cases) are manufacturing agreements of one type or another, and only 8 of the agreements are more general or "pure" technology transfers in the sense that no manufacturing rights are specified. For 53 per cent of the innovations, the right to use of a trademark was also provided, and in this respect, there was not much difference between the agreements of Canadian- and foreign-controlled firms.

The exclusive right to manufacture was much less often specified in the agreements (46 per cent of the agreements) and the same was true of exclusive rights to sell the resulting products (43 per cent). Here, too, the agreements of the Canadian-controlled firms more often specified exclusive rights.

In respect of territorial restrictions, restrictions on where the recipient could manufacture were specified in 42 per cent of the transfer agreements, being more common in the agreements of foreign-controlled firms. A smaller proportion (35 per cent) of the agreements contained territorial restrictions on sales and, in this respect, the difference between Canadian-controlled firms is not great (32 per cent vs. 36 per cent). However, a large difference does exist between Canadian- and foreign-controlled firms with respect to the severity of the territorial restrictions on sales. Whereas only 50 per cent of the territorially restricted transfers to Canadian-controlled firms confine the firm to selling solely in Canada, 83 per cent of the restricted transfers to foreign-controlled firms do so.

The evidence on this important subject is, therefore, mixed. Little difference was found between Canadian- and foreign-controlled firms in respect of the percentage of transfers which restrict the recipient as to where he may sell, and only about one-third of the transfers contained such restrictions. However, where the restrictions are found, the foreign-controlled firm is much more often confined completely to the Canadian market.

Finally, none of the technology transfer agreements of Canadian-controlled firms specified where inputs required in the production process, based on the technology being transferred, had to be sourced and only 3 per cent of the agreements of foreign-controlled firms contained such restrictions.

In order to more fully appreciate the differences discussed above in respect of foreign- and Canadian-controlled firms, it is worthwhile to examine these same aspects of the agreements in terms of differences between intracorporate MNE and arm's-length agreements (Table 11). Most of the intracorporate transfers provide for continuous technology transfers, and only half of them are in writing. Relatively very high proportions of these agreements specify rights to manufacture (82 per cent), to use in manufacture (94 per cent), and rights to use of a trademark (62 per cent). The frequency of the specifications of these rights for the intracorporate transfers are high relative to all the other comparisons made in Tables 10 and 11. This indicates that a relatively very complete transfer of technology is being effected under these intracorporate arrangements.

Table 11

NATURE OF TECHNOLOGY TRANSFER AGREEMENT, MNE AND ARM'S-LENGTH TRANSFERS

Conditions of Agreement	TOTAL			Intracorporate MNE			ARM'S LENGTH		
	No. of Respondents	No. Indicating "Yes"	% of Total Respondents Indicating "Yes"	No. of Respondents	No. Indicating "Yes"	% of Total Respondents Indicating "Yes"	No. of Respondents	No. Indicating "Yes"	% of Total Respondents Indicating "Yes"
	No.	No.	%	No.	No.	%	No.	No.	%
Continuous	84	62	73.8	53	47	88.7	31	15	48.4
One-time	84	22	26.2	53	6	11.3	31	16	51.6
Cross licence	77	6	7.8	51	3	5.9	26	3	11.5
Written	79	51	64.6	52	27	51.9	27	24	88.9
Gives right to manufacture	64	47	73.4	39	32	82.1	25	15	60.0
Gives right to sell	68	46	67.6	42	30	71.4	26	16	61.5
Gives right to use in manufacture	55	47	85.5	33	31	93.9	22	16	72.7
Gives right to use of trademark	56	31	55.4	34	21	61.8	22	10	45.5
Specifies territory of manufacture	72	33	45.8	48	22	45.8	24	11	45.8
Specifies territory of sales	72	26	36.1	48	18	37.5	24	8	33.3
Gives exclusive right to manufacture	62	27	43.5	42	19	45.2	20	8	40.0
Gives exclusive right to sell	62	25	40.3	42	18	42.9	20	7	35.0
Specifies input sources	66	2	3.0	45	1	2.2	21	1	4.8
Total No. of cases	85			53			32		

On the other hand, when we examine the remaining aspects of the transfers, the tendency to grant exclusive rights and the frequency of territorial and input source restrictions, the difference between the intracorporate agreements and those of arm's-length agreements (or the agreements of Canadian- and foreign-controlled firms in general) are not very great. Intracorporate transfers specify exclusive rights a little more often than do arm's-length agreements and also specify territorial restrictions on sales to a slightly greater degree. Of the total of 30 agreements in which exclusive rights to sell are granted to the technology recipient (Table 10), 20 (67 per cent) also restrict the recipient as to the territory where he may sell the products produced under the technology. In 16 of the 20 cases (80 per cent), the recipient is restricted to selling solely in Canada. For transfers made on an intracorporate basis, the granting of exclusive rights to sell is relatively more frequent and at the same time, a slightly greater proportion of the exclusive agreements -- 13 of a total of 18 (72 per cent) -- restrict the subsidiary as to sales territories. In 11 of these 13 cases (85 per cent), the subsidiary is restricted to selling solely in Canada. The placing of territorial restrictions on sales is very infrequent (only 17 per cent) for the 40 transfers which did <u>not</u> grant exclusive rights to sell. This confirms the fact that the granting of exclusive rights to sell is strongly associated with the placing of restrictions on where the technology recipient may sell the products he produces using the externally acquired technology. This relationship is strongest in respect of intracorporate MNE transfers. Also the severity of the territorial restrictions on sales is greater for the intracorporate MNE transfers, since 83 per cent of the intracorporate transfers that contain restrictions on sales territories restrict the subsidiary to sales in Canada, whereas 63 per cent of the arm's-length agreements restrict the recipient to sales in Canada.

Finally, implicit in the above analysis is a comparison of the <u>arm's-length agreements of Canadian- and foreign-controlled firms</u>. This is set out in Table 12. When we exclude the intracorporate transfers of MNEs from the analysis and just compare arm's-length transfers between the two types of firms, we find the technology package going to Canadian-controlled firms was much more comprehensive than that being acquired by foreign-controlled firms on an arm's-length basis. This is what one would expect, given that the Canadian subsidiaries would normally only be going outside the MNE for specialized technology (where the technology is not available within the MNE or where very superior technology is available externally). Even so, foreign-controlled subsidiaries obtained continuous access to the technology more often than did Canadian-controlled firms.

It is also interesting to note that the Canadian subsidiaries when dealing at arm's-length, obtained exclusive rights less often than did Canadian-controlled firms, though this too might reflect the fact that the foreign-controlled firms were acquiring less of a technology package in these cases. Territorial restrictions on sales occurred with equal frequency in the arm's-length agreements of the two types of firms (i.e., in one-third of the cases).

To summarize, firms acquiring technology externally can be placed into three major groups. First, there are foreign-controlled firms obtaining technology on an <u>intra-MNE basis</u>. "Other transfer agreements" providing for a continuous and relatively complete flow of technology to the Canadian subsidiary were the predominant means of effecting technology transfers for the foreign-controlled firms. Exclusive rights were more often given to the subsidiary in terms of manufacturing and selling than for other types of transfers, but the subsidiaries were relatively severely constrained in terms of the territories where manufacturing and selling could take place. Manufacturing abroad or exporting products related to the transferred technology were more often prohibited than is the case for other types of technology recipient.

Table 12

NATURE OF ARM'S-LENGTH TRANSFER AGREEMENTS, BY CONTROL

Conditions of Agreement	TOTAL ARMS' LENGTH			CANADIAN-CONTROLLED			FOREIGN-CONTROLLED		
	No. of Respondents	No. Indicating "Yes"	% of Total Respondents Indicating "Yes"	No. of Respondents	No. Indicating "Yes"	% of Total Respondents Indicating "Yes"	No. of Respondents	No. Indicating "Yes"	% of Total Respondents Indicating "Yes"
	No.	No.	%	No.	No.	%	No.	No.	%
Continuous	31	15	48.4	16	7	43.8	15	8	53.3
One-time	31	16	51.6	16	9	56.2	15	7	46.7
Cross licence	26	3	11.5	14	1	7.1	12	2	16.7
Written	27	24	88.9	15	12	80.0	12	12	100.0
Gives right to manufacture	25	15	60.0	14	10	71.4	11	5	45.5
Gives right to sell	26	16	61.5	14	11	78.6	12	5	41.7
Gives right to use in manufacture	22	16	72.7	10	9	90.0	12	7	58.3
Gives right to use of trademark	22	10	45.5	12	6	50.0	10	4	40.0
Specifies territory of manufacture	24	11	45.8	15	5	33.3	9	6	66.7
Specifies territory of sales	24	8	33.3	15	5	33.3	9	3	33.3
Gives exclusive right to manufacture	20	8	40.0	11	5	45.5	9	3	33.3
Gives exclusive right to sell	20	7	35.0	11	5	45.5	9	2	22.2
Specifies input sources	21	1	4.8	13	0	0.0	8	1	12.5
Total No. of cases	32			16			16		

The second group consists of arm's-length transfers to foreign-controlled firms, which represent 30 per cent (N=22) of all transfers to foreign-controlled firms. The predominant external sources used were suppliers and consultants. The technology package acquired was not extensive. Exclusive rights to manufacture and to sell were infrequently given, but when they were, the technology recipient frequently was restricted to manufacturing and selling in Canada only. The use of license agreements to effect the technology transfer was relatively more common than in the case of intra-MNE transfers and the relative incidence of one-time transfers of a particular technology was greater. Small foreign-controlled firms were most heavily dependent upon external sources of technology (both MNE and arm's-length); however, since most foreign-controlled firms are large, most of the technology transfers were going to the large foreign-controlled firms.

Arm's-length technology transfers to Canadian-controlled firms form the third major group of firms acquiring technology from a source outside the firm. The predominant sources of technology were suppliers, consultants, and partners in joint ventures. Sixty per cent of the transfers were to smaller Canadian-controlled firms (employing less than 200 persons), and these firms were acquiring extensive technology packages.

Overall, the acquisition of technology from external sources via these agreements forms a small proportion of the innovations reported in the survey, in that 96 of the 283 innovations reported by firms (34 per cent) were based wholly or partly upon externally-acquired technology. Almost all of the technology was obtained from sources outside Canada, and external sources of technology other than intra-corporate MNE sources were relatively rarely used.

Other Aspects of Technology Transfers

As discussed in Chapter III, the external acquisition of technology to a large extent takes the place of internally conducted basic and applied research. One would expect, then, that the length of time which a firm spends on R&D and manufacturing and marketing start-up, that is, the commercialization period, would be shorter for innovations based on externally acquired technology than for those created via in-house R&D. The impact upon lag rates associated with particular innovations (that is, the number of years elapsed from the first world launch or use by the firm reporting the innovation), is more problematical. A number of factors, such as type of innovation (product or process), its complexity, firm characteristics, and the source of technology (internal or external, MNE vs. arm's-length), bear upon lag rates. Following a discussion of commercialization periods, lag rates will be examined by source of technology, origin of control of firm by industry, and by type of transfer.

Commercialization Periods

As expected, the commercialization period associated with internal R&D is longer than that associated with innovations utilizing technology acquired from a source outside the firm. This is the case regardless of whether a firm is Canadian- or foreign-controlled and is characteristic of both product and process innovations (Table 13).

Table 13

COMMERCIALIZATION PERIOD,* BY SOURCE OF TECHNOLOGY AND CONTROL, ALL INDUSTRIES

Primary Source of Technology	All Innovations		Product Innovations		Process Innovations	
	No.	Mean No. of Months	No.	Mean No. of Months	No.	Mean No. of Months
Canadian-Controlled	119	21	95	20	24	24
In-House R&D	98	21	83	20	15	28
Externally Acquired	21	19	12	19	9	18
Foreign-Controlled	156	26	101	23	55	33
In-House R&D	86	29	63	25	23	41
Externally Acquired	70	22	38	18	32	27
Total	275	24	196	21	79	30
In-House R&D	184	25	146	22	38	36
Externally Acquired	91	21	50	19	41	25

*Average number of months from first allocation of R&D resources to first commercial launch (products) or use (processes).

However, the length of the commercialization period associated with innovations by Canadian- and foreign-controlled firms is strongly affected by the type of technology transfer agreement, that is, whether it is a license or an "other transfer agreement" (Table 14). For all externally acquired innovations taken as a whole, the commercialization period is much longer for licenses than for "other transfer agreements"; in fact, commercialization periods associated with licenses exceed in duration those associated with internal R&D. This is the case for both products and processes externally acquired by Canadian- and foreign-controlled firms.

Table 14

COMMERCIALIZATION PERIOD, BY TYPE OF TRANSFER AGREEMENT AND CONTROL, ALL INDUSTRIES

Type of Transfer Agreement	All Innovations		Product Innovations		Process Innovations	
	No.	Mean No. of Months	No.	Mean No. of Months	No.	Mean No. of Months
Canadian-Controlled						
License	12	25	11	26	1	18
Other Transfer Agreement	7	18	4	17	3	18
Foreign-Controlled						
License	17	32	9	27	8	37
Other Transfer Agreement	55	20	36	20	19	20
Total						
License	29	29	20	27	9	34
Other Transfer Agreement	62	20	40	20	22	19

Similarly, technology transferred both within MNEs and on an arm's-length basis requires a shorter commercialization period when an "other transfer agreement" rather than a license is used (Table 15). Again, this is the case for both products and processes.

It is apparent, therefore, that technology transferred via "other transfer agreements", most of which consist of continuous transfers under master agreements between a foreign parent company and its Canadian subsidiary, not only means the technology is being made available when otherwise it might not be developed at all or only at a relatively high cost, but also makes it possible to adopt innovations from abroad more quickly. License agreements, on the other hand, regardless of the source of the technology, require a significant amount of further in-house effort in order to integrate the technology into a firm's current operations.

Table 15

COMMERCIALIZATION PERIOD, BY TYPE OF TRANSFER AGREEMENT, MNE AND ARM'S-LENGTH TRANSFERS

Type of Transfer Agreement	All Innovations		Product Innovations		Process Innovations	
	No.	Mean No. of Months	No.	Mean No. of Months	No.	Mean No. of Months
MNE Transfers	53	21	35	18	18	28
License	11	30	6	21	5	40
Other Transfer Agreement	42	19	29	17	13	23
Arm's-Length Transfers	38	22	15	20	23	23
License	13	21	9	18	4	28
Other Transfer Agreement	14	18	6	24*	8	14

*There is a single case of a transfer in the smelting and refining industry which has a commercialization period of 60 months. When this extreme case is removed, the overall commercialization period for arm's-length "other transfer agreements" is shorter than that for licenses.

Lag Rates

This section examines lag rates in some detail. The lag rate refers to the time between the first known launch or use of an innovation elsewhere in the world and the first launch or use of the innovation by the reporting firm in Canada. In reporting their major innovations, firms were asked to estimate the date and country of the introduction of the innovation (or a very similar one) if the reported innovation was not original to the firm. In this respect, lag rates are a measure of how quickly major innovations abroad are being introduced into Canadian industry. As mentioned above, there are a large number of factors influencing these lag rates -- e.g., the complexity of the innovation, its appropriateness to economic conditions in Canada, the source of the technology for the innovation, etc. In this section, we examine lag rates by type of innovation (product vs. process), by source of technology, for Canadian- and foreign-controlled firms by industry, and for innovations where technology transfers were effected at arm's-length vs. intracorporate MNE transfers. The number of cases examined is not large, so it is difficult to generalize from the results, particularly given the large number of factors influencing lag rates which were not controlled and the extreme variability in the observed lag rates. Both mean and median values are given in the tables.

When lag rates on imitative innovations are examined by source of technology, there is a tendency for product innovations based on imported technology to be more quickly introduced into Canada than is the case for those which copy innovations developed abroad via the in-house development of the technology (Table 16). On the other hand, this relationship appears to be reversed in respect of process innovations, where the median lag rate for imitative innovations based on technology developed via internal R&D is only 2 years, compared to a 5-year lag rate for innovations employing technology from an external source. This may reflect the fact that the process technologies which firms obtain externally are complex and are directed to introducing innovations which are not easily integrated into the operations of the firms.

Table 16

LAG RATE, BY SOURCE OF TECHNOLOGY AND CONTROL, ALL INDUSTRIES

Primary Source of Technology	Product Innovations			Process Innovations		
	No.	Mean Lag Rate	Median Lag Rate	No.	Mean Lag Rate	Median Lag Rate
		(Years)	(Years)		(Years)	(Years)
Canadian-Controlled	29	6.6	3.5	10	15.2	8.0
In-House R&D	22	7.4	5.0	5	14.4	8.5
Externally Acquired	7	4.0	2.0	5	16.2	5.5
Foreign-Controlled	48	7.8	5.0	24	5.9	4.0
In-House R&D	21	10.0	5.5	7	5.0	1.0
Externally Acquired	27	6.1	5.0	17	6.3	4.5
Total	77	7.4	5.0	34	8.7	5.0
In-House R&D	43	8.7	5.5	12	8.9	2.0
Externally Acquired	34	5.7	5.0	22	8.5	5.0

When we examine lag rates by source of technology for the innovations of foreign- and Canadian-controlled firms separately, we find that lag rates on product innovations based on externally acquired technologies for both types of firms are shorter than those associated with the in-house development of the necessary technologies. This difference is much more marked for Canadian-controlled firms. In addition, the lag rate for product innovations based on externally acquired technologies is shorter for Canadian-controlled firms than for foreign-controlled firms, though this is to a degree an industry mix phenomenon.

In the case of process innovations, the lag rates on the introduction of innovations by Canadian-controlled firms are long relative to those for foreign-controlled firms. The lag rates for process innovations of Canadian-controlled firms are shorter when the technology is imported. However, for foreign-controlled firms, the lag rates for innovations based on imported technologies are considerably longer than for their innovations based on technologies developed in-house. Again, this raises the issue of whether the types of process innovations being developed by foreign-controlled firms utilizing imported technologies are innovations which are difficult to introduce into Canadian industry easily or quickly for any of a number of reasons.

Lag rates in adopting important innovations developed abroad vary significantly across the five industries . In Table 17 it can be seen that with two exceptions, foreign-controlled firms were quicker in introducing innovations into Canada which had already been introduced abroad for both process and product innovations. Only in the telecommunications equipment and electrical industrial equipment industries were Canadian-controlled firms quicker to adopt product innovations first introduced abroad. In the smelting and refining and crude petroleum production industries, on the other hand, foreign-controlled firms are very much quicker to adopt process technologies developed abroad.

Table 17

LAG RATES BY TYPE OF INNOVATION AND CONTROL, BY INDUSTRY

	Product Innovations			Process Innovations		
Industry	No.	Mean Lag Rate	Median Lag Rate	No.	Mean Lag Rate	Median Lag Rate
		(Years)	(Years)		(Years)	(Years
Telecommunications Equipment and Components						
Canadian-Controlled	15	5.4	2.0	2	6.0	4.0
Foreign-Controlled	16	5.5	5.0	3	5.7	4.0
Electrical Industrial Equipment						
Canadian-Controlled	9	7.1	2.0	0	--	--
Foreign-Controlled	18	10.4	7.0	1	5.0	5.0
Plastics Compounds and Synthetic Resins						
Canadian-Controlled	4	10.3	7.0	2	8.0	7.0
Foreign-Controlled	10	6.4	4.0	5	7.0	3.0
Smelting and Refining						
Canadian-Controlled	0	--	--	3	26.3	24.0
Foreign-Controlled	3	10.3	3.0	9	6.9	2.5
Crude Petroleum Production						
Canadian-Controlled	0	--	--	3	15.3	1.5
Foreign-Controlled	1	5.0	5.0	1	3.8	1.0

As can be seen in Table 18, the shorter lag rates associated with process innovations of foreign-controlled firms, when compared to Canadian-controlled firms, is being influenced by their better access to process technologies being developed abroad by parent and affiliated firms. Intracorporate transfers of process technologies show a lag rate or 4.5 years as opposed to 5.5 years on arm's-length technology transfers for process innovations. In contrast, intra-MNE transfers of product technologies show considerably longer lag rates than do arm's-length product technology transfers. When it is recalled that all of the intra-MNE transfers but one are to foreign-controlled firms and that all of the transfers to Canadian-controlled firms are made on an arm's-length basis, it appears the differences in lag rates on product and process technologies by control are being influenced by the nature of the relationship between technology sources and recipients. Canadian subsidiaries of foreign-based companies benefit from access to information and R&D and technology pools which are associated with large organizations, particularly those which are oriented towards international developments in process technology. In contrast, product technologies, when transferred on an arm's-length basis show faster rates of adoption than those transferred within MNEs. Again, this may reflect the nature of the technologies being transferred and the complexity of the innovations being developed.

Table 18

LAG RATE, BY TYPE OF TRANSFER AGREEMENT,
INTRA-MNE AND ARM'S-LENGTH TRANSFERS

Type of Transfer Agreement	Product Innovations			Process Innovations		
	No.	Mean Lag Rate	Median Lag Rate	No.	Mean Lag Rate	Median Lag Rate
		(Years)	(Years)		(Years)	(Years)
Intra-MNE	26	6.1	5.0	11	5.1	4.5
Arm's-Length	8	4.4	2.0	11	12.0	5.5

In summary, it is difficult to generalize on the basis of the above information because the samples are small and the lag rates are being influenced by a number of factors for which we were unable to control. What does seem to emerge, is a tendency for foreign-controlled firms to be quicker to adopt important process innovations developed abroad because of their ties with parent and affiliated firms abroad. However, this is not the case in respect of product innovations where the evidence is that Canadian-controlled firms are adopting product innovations relatively quickly. In addition, lag rates on innovations based on externally acquired technologies appear to be shorter than those for innovations based on technology developed in-house, in all cases except for the process innovations of foreign-controlled firms. The lag rates for foreign-controlled firms in adopting process innovations based on externally acquired technologies are not long (in fact, they are shorter than for Canadian-controlled firms) but the lag rates on their process technologies developed in-house are very short, indicating a tendency for foreign-controlled firms to import the technology where the process innovations are very complex.

Summary

The technological basis of the majority (66 per cent) of the innovations reported in this survey by all firms have been developed through in-house R&D effort. A further 7 per cent utilized both technology developed in-house and externally acquired technology. The remaining 27 per cent of the reported innovations utilized externally acquired technology exclusively.

The propensity to acquire technology from a source external to the firm is relatively greater among some sub groups, particularly among very small and very large foreign-controlled firms which relied in whole or in part on external technology for 65 and 45 per cent of their innovations, respectively. Canadian-controlled firms use external sources much less frequently and this finding holds across each of the five industries. Overall, medium sized firms, both foreign- and Canadian-controlled, seldom utilize externally acquired technologies.

Most of the innovations based on externally acquired technology draw upon non-domestic technology sources (85 per cent). The technology for 66 per cent of the innovations utilizing externally acquired technology was acquired from the United States. The few Canadian technology sources utilized consisted largely of consultants.

In those cases where firms did acquire technology externally, it was obtained from parent or affiliated firms abroad in 55 per cent of the cases. The acquisition of technology from each of the other external sources was relatively rare. Suppliers and consultants were most often used (13 and 11 cases of technology transfers, respectively). There are greater differences in the frequency of utilization of external technology sources between Canadian- and foreign-controlled firms, reflecting an apparent lack of significant intracorporate technology sources for Canadian-controlled firms in general.

Process innovations represented 29 per cent of all reported innovations in the survey. However, when we examined innovations based in whole or in part on externally acquired technologies, we find that 55 per cent of these innovations are process innovations. There is a marked tendency, therefore, for firms to develop new and improved products in-house but to utilize outside technology in the development of process innovations. Forty per cent of the process innovations of Canadian-controlled firms were based in whole or part on externally acquired technologies, while 58 per cent of those of foreign-controlled firms were based on externally acquired technologies.

Only a small proportion of the technology transfer agreements (30 per cent) were formal licensing agreements. This is because most of the technology transfer agreements involving foreign-controlled firms are not licensing agreements but are rather transfers effected under master agreements with parent firms. Even the arm's-length technology transfers to foreign-controlled firms were not predominantly under formal licensing agreements. Sixty per cent of the technology transfers involving Canadian-controlled firms, however, involved formal licensing agreements.

The vast majority of technology transfers (70 cases) are manufacturing agreements providing for either the right to manufacture or the right to use the technology in manufacturing processes, or both. Only 8 of the agreements are more general or "pure" technology transfers in the sense that no provision for manufacturing rights was specified.

Foreign-controlled firms relied upon intracorporate sources of technology in 52 (70 per cent) of the 74 cases of transfers to foreign-controlled firms; arm's-length sources were involved in the remaining 22 (30 per cent) cases. Thus,in almost 1/3 of the cases where the Canadian subsidiary relied upon externally acquired technology, it went outside the MNE to acquire the technology. In contrast, 21 of the 22 transfers to Candian-controlled firms occurred on an arm's-length basis; a single intracorporate transfer was made from a United States-based affiliate to a Canadian-controlled firm.

The intracorporate technology transfer agreements tended more often to be continuous and to represent a complete technology transfer in the sense that they more frequently provided for a more complete range of manufacturing and trademark use rights than do the agreements involving Canadian-controlled firms. They are less often in writing. On the other hand, when these aspects of technology transfers are compared for only the arm's-length transfers of foreign-controlled and Canadian-controlled firms, the opposite result occurs -- the arm's-length transfers to foreign-controlled firms tended to be the least complete, though they were a little more often continuous than was the case for Canadian-controlled firms.

Territorial restrictions on the manufacture and sale of the products resulting from the transferred technologies were included in about 42 and 34 per cent of the agreements respectively, and the percentage tended to be a little higher in the case of the intracorporate MNE agreements. In respect of just those agreements which do have territorial restrictions on the sale of the resulting products, the intracorporate MNE transfers more often restricted the recipient solely to selling in Canada (83 per cent of the agreements) than is the case for those restricted agreements of Canadian-controlled firms where the restriction to Canada is present in only 50 per cent of the cases.

Exclusive rights to manufacture and sell were included in 46 and 43 per cent respectively of all technology agreements. Further, they were most often contained in the technology transfer agreements of the Canadian-controlled firms.

The frequency of occurrence of exclusive rights in the technology agreements is strongly associated with the presence and severity of territorial restrictions on sales and the association is a little stronger in the case of intracorporate MNE transfer agreements, as might be expected.

Restrictions on sources of inputs to be used in conjunction with the imported technology appear to be extremely rare, occurring in only 2 of the transfer agreements involving foreign-controlled firms and in none of the agreements involving Canadian-controlled firms.

Turning now to commercialization periods and lag rates, it is found that innovations developed through in-house R&D required longer periods of time to commercialize than innovations which were based on technology acquired from an external source. This is affected, however, by the type of transfer agreement used. Commercialization periods associated with "other transfer agreements" were shortest, followed by commercialization periods associated with in-house R&D. Technology transferred via licensing agreements, on the other hand, required a significant amount of further in-house effort in order to integrate the technology into the firm's current operations.

The evidence with regard to lag rates is more mixed. Median lag rates on product innovations which are based on externally acquired technology for both Canadian- and foreign-controlled firms were shorter than those associated with the in-house development of technology. Canadian-controlled firms also adopt process innovations based on externally acquired technology more quickly than when the technology is developed in-house, but this is not the case for innovations of foreign-controlled firms. In the latter case, the lag rates on innovations based on externally acquired technology, though not long (in fact, they are shorter than for externally acquired technologies for Canadian-controlled firms) exceed the lag rates associated with the in-house development of process technologies which are very short. This may indicate that foreign-controlled firms have a tendency to import the technology where the process innovations are relatively very complex.

Chapter V

TECHNOLOGICAL CHANGE IN CANADIAN- AND FOREIGN-CONTROLLED FIRMS

In Canadian industrial policy discussions, the issue which has received the most attention has been the foreign control issue -- i.e., the costs and benefits to the Canadian economy of the extremely high degree of foreign control (primarily U.S.) of firms in Canadian industry. This chapter addressed the issues by analysing differences between Canadian- and foreign-controlled firms in respect of innovations and technological change. We find some significant differences.

Foreign-controlled firms represent 52 per cent of total reporting firms and account for 57 per cent of the reported innovations in our survey. The table below sets out the country of control of respondent firms in the five industries.

Table 1

COUNTRY OF CONTROL OF REPORTING FIRMS BY INDUSTRY

Country of Control	All Firms		Telecommunications Equipment		Electrical Industrial Equipment		Plastics & Synthetic Resins		Smelting and Refining		Crude Petroleum Production	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Canada	80	48	37	57	24	48	9	43	5	36	4	25
United States	63	38	20	31	16	32	10	48	8	57	9	56
United Kingdom	11	7	6	9	2	4	1	5	1	7	1	6
West Germany	3	2	1	2	1	2	1	5				
France	2	1			2	4						
Scandinavia	3	2			3	6						
Switzerland	1	0.1			1	2						
Belgium	1	0.1									1	6
Holland	3	2	1	2	1	2					1	6
Total	167	100	65	100	50	100	21	100	14	100	16	100

Of the 167 firms for which country of control could be established, 48 per cent are Canadian-controlled, with one-third of these being subsidiaries of other Canadian-controlled firms. Foreign-controlled firms, which form 52 per cent of the sample, are predominantly U.S. -based -- 38 per cent of all reporting firms. Ownership of the remaining firms is distributed among several Western European countries (Table 1). The level of foreign control of respondents is highest in the smelting and refining and crude petroleum production industries and lowest in the telecommunications equipment and components and electrical industrial equipment industries. In each industry, U.S. - based firms are predominant within the foreign-control group.

The distribution of firm sizes within the group of domestically-controlled firms forms almost a mirror image of that within the foreign-controlled group: 69 per cent of all Canadian-controlled firms employ 100 people or less and 31 per cent employ more than 200 people. On the other hand, firms employing 100 people or less comprise 36 per cent of all foreign-controlled firms while 63 per cent employ more than 200 people (Table 2). The result is that foreign-controlled firms account for 72 per cent of all reporting firms with more than 200 employees and 75 per cent of all firms with 500 or more employees. On the other hand, Canadian-controlled firm account for 64 per cent of all firms with 100 employees or less.

Table 2

AVERAGE SIZE OF REPORTING FIRMS,
CANADIAN- AND FOREIGN-CONTROLLED, 1978

Firm Size	Canadian-Controlled		Foreign-Controlled	
	No.	%	No.	%
0-50 employees	42	54	19	22
51-100 employees	12	15	12	14
101-200 employees	10	13	18	21
201-500 employees	8	10	18	21
500 or more employees	6	8	18	21
Total number of firms	78		85	

Overall, the median level of sales by firms in 1978 for each of the five industries is greater for foreign- than for Canadian-controlled firms. Even where the employment size of firms is similar, foreign-controlled firms tend to have higher levels of sales than Canadian-controlled firms. This is in part a result of the fact that reporting foreign-controlled firms are often importing and selling products in Canada which parents or affiliates have produced, but it could also reflect, to some degree, differences in productivity.

Table 3

MEDIAN LEVEL OF SALES,
BY SIZE OF FIRM AND ORIGIN OF CONTROL, 1978

Firm Size	Canadian-Controlled	Foreign-Controlled
	($)	($)
0-50 employees	600,000	1,700,000
0-100 employees	1,136,000	3,000,000
0-200 employees	1,500,000	4,600,000
0-500 employees	1,681,500	6,600,000
More than 500 employees	45,615,344	155,000,000
All Firms	7,600,000	9,800,000

Thus the reporting foreign-controlled firms are considerably larger in terms of sales and employment bases than the Canadian-controlled firms.

Basic Characteristics of the Innovations of Canadian- and Foreign-Controlled Firms

Foreign-controlled firms are more process innovation-oriented than Canadian-controlled firms (Table 4). Process innovations represent 35 per cent of the total innovations reported by foreign-controlled firms. As a result, foreign-controlled firms account for 70 per cent of all reported process innovations in the survey. In addition, the foreign-controlled firms reported a higher percentage of their process innovations as new process innovations, and a considerably lower percentage of their product innovations as new product innovations than was the case for the Canadian-controlled firms. Thus, foreign-controlled firms appear to be making a particularly significant contribution to the development and introduction of process innovations into Canadian industries.

Table 4

INNOVATIONS BY TYPE BY FOREIGN AND CANADIAN CONTROL

Type of Innovation	Canadian-Controlled		Foreign-Controlled	
	No. of Innovations	% Canadian Total	No. of Innovations	% Foreign Total
Product	96	79	105	65
Process	25	21	57	35
Total	121	100	162	100
New Product	69	72	63	60
Improved Product	27	28	42	40
Total	96	100	105	100
New Process	10	40	29	51
Improved Process	15	60	28	49
Total	25	100	57	100

The greater process-orientation of the foreign-controlled firms reflects their relatively stronger participation in the more process-oriented industries. Innovations by Canadian-controlled firms, as a percentage of total innovations reported, by industry, were 55 per cent in telecommunications equipment and components, 43 per cent in electrical industrial equipment, 38 per cent in plastics compounds and synthetic resins, 30 per cent in smelting and refining, and 17 per cent in crude petroleum production. Thus the more process-oriented the industry the lower the share of the Canadian-controlled firms. As can be seen in Table 5, foreign-controlled firms retain their dominant position in respect of process innovations even within each industry, with the exception of electrical industrial equipment.

Table 5

PRODUCT AND PROCESS INNOVATIONS
BY INDUSTRY AND ORIGIN OF CONTROL

	Innovations by Canadian-Controlled Firms				Innovations by Foreign-Controlled Firms			
	Product		Process		Product		Process	
Industry	No.	% Total Product	No.	% Total Process	No.	% Total Product	No.	% Total Process
Telecommunications Equipment and Components	55	56	4	40	43	44	6	60
Electrical Industrial Equipment	25	41	4	57	36	59	3	43
Plastics Compounds and Synthetic Resins	12	43	3	25	16	57	9	75
Smelting and Refining	1	14	9	35	6	86	17	65
Crude Petroleum Exploration and Production	0	0	5	19	3	100	22	81

A comparison of the time devoted to the development of the reported innovations also shows differences between Canadian- and foreign-controlled firms. The following table compares the average periods of time spent on developing product and process innovations by the two types of firm. Again, the significant difference is found in the considerably longer period of time which foreign-controlled firms spend on the development of their process innovations (33 months vs. 24 for Canadian-controlled firms).

Table 6

AVERAGE NUMBER OF MONTHS TO FIRST COMMERCIAL LAUNCH
OR FIRST USE OF INNOVATION -- BY ORIGIN OF CONTROL OF FIRM

	Canadian-Controlled Firms			Foreign-Controlled Firms		
Type of Innovation	No. of Innovations	Mean No. of Months	Median No. of Months	No. of Innovations	Mean No. of Months	Median No. of Months
All Innovations	119	21	14	156	26	18
Product	95	20	14	101	23	18
Process	24	24	18	55	33	24

One can also compare the pay-back periods for innovations of Canadian-controlled and foreign-controlled firms. Foreign-controlled firms generally have longer pay-back periods than their Canadian-controlled counterparts (Table 7). This is influenced by the fact that foreign-controlled firms are, on average, larger than Canadian-controlled firms, their innovations are more costly, and longer periods are devoted to their development. It is notable that only two process innovations

Table 7

PAY-BACK PERIODS ON INNOVATIONS
BY ORIGIN OF CONTROL OF FIRM

	Less than 3 Years		3-5 Years		More than 5 Years	
	No. of Innovations	%	No. of Innovations	%	No. of Innovations	%
Canadian-Controlled Firms						
All Innovations	68	61	30	27	14	13
Product Innovations	54	61	23	26	12	13
Process Innovations	14	61	7	30	2	9
Foreign-Controlled Firms						
All Innovations	74	49	48	32	29	19
Product Innovations	50	50	35	35	16	16
Process Innovations	24	48	13	13	13	26

of Canadian-controlled firms (9 per cent of their process innovations) had a pay-back period in excess of 5 years in contrast to foreign-controlled firms where 26 per cent of process innovations had a pay-back period of this length.

One final basic characteristic of the innovations of the two types of firm is the distinction between original and imitative innovations. Out of 281 innovations, 148 or 53 per cent were original to Canada (i.e., had no prior first launch or use anywhere in the world). The remaining 133 innovations (47 per cent of the total) were in imitation of innovations first launched elsewhere (primarily abroad). The following table sets out original and imitative innovations by control.

Table 8

ORIGINAL vs. IMITATIVE
INNOVATIONS BY FIRM CONTROL

Control	Original Innovations: All Innovations	Original Innovations: Product	Original Innovations: Process	Imitative Innovations: All Innovations	Imitative Innovations: Product	Imitative Innovations: Process	Imitative as % of Total: All Innovations	Imitative as % of Total: Product	Imitative as % of Total: Process
		-- No. --			-- No. --			-- % --	
Canadian-Controlled Firms	71	59	12	49	36	13	41	38	52
Foreign-Controlled Firms	77	50	27	84	54	30	52	52	52

Foreign-controlled firms exhibit a tendency to more often imitate major innovations being developed and introduced (primarily) abroad. For foreign-controlled firms, 52 per cent of their reported innovations, both product and process, were in imitation of innovations which had their first launch or use elsewhere in the world (mostly in the United States). Canadian-controlled firms also introduced major process innovations which were in imitation of foreign developments in respect of 52 per cent of their reported innovations, but only 38 per cent of their product innovations were imitative. To a degree, this reflects the relatively heavy participation of Canadian-controlled firms in the telecommunications equipment industry where imitation rates are relatively low (Table 9). Only in crude petroleum production are imitation rates of Canadian-controlled firms higher than those of foreign-controlled firms. Clearly, the imitation process is an extremely important one for both types of firm.

Table 9

ORIGINAL vs. IMITATIVE INNOVATIONS
BY INDUSTRY AND ORIGIN OF CONTROL

Industry	Imitations		Originals		Imitations as % of Total	
	Canadian No.	Foreign No.	Canadian No.	Foreign No.	Canadian %	Foreign %
Telecommunications Equipment & Components	19	21	39	27	33	44
Electrical Industrial Equipment	14	23	15	16	48	59
Plastics Compounds & Synthetic Resins	8	17	7	8	53	68
Smelting & Refining	4	14	6	9	40	61
Crude Petroleum Production and Exploration	3	8	2	17	60	32

The effective and rapid adoption of technologies being employed around the world in the development of new and improved products and production processes can and clearly does play an important role in the innovation process in Canada. This is a particularly important issue, given the large number of innovations which are based on innovative developments around the world.

The length of time elapsed from the first world launch or use of a new or improved product or process until the first launch or use of it by the reporting firm (referred to as the lag rate), is an issue which is discussed in detail in Chapter IV and so only a few brief remarks will be made here relating to differences in lag rates across control.

With regard to product innovations, Canadian-controlled firms are quicker in imitating innovations first introduced abroad than are foreign-controlled firms, the lag rates being 3.5 and 5.0 years, respectively. The major portion of the difference arises out of the much faster speed with which Canadian-controlled firms imitate products when using technology acquired externally.

In respect of process innovations, however, foreign-controlled firms are quicker than Canadian-controlled firms at imitating innovations first introduced abroad. This is the case whether or not the technology was developed in-house or acquired from an external source. This is yet another indication of the relative emphasis placed by foreign-controlled firms on process technology: they are more process-oriented in terms of numbers of innovations, the length of time they devote to the development of such innovations, and the alacrity with which they imitate important process technologies being developed by firms abroad.

Sources of Technology for Innovations: Canadian- and Foreign-Controlled Firms

An examination of the primary sources of technology relied upon by firms in developing their major innovations shows that Canadian-controlled firms more often utilize technologies based upon internal R&D than do foreign-controlled firms (Table 10).

Table 10

PRIMARY SOURCE OF TECHNOLOGY, CANADIAN- AND FOREIGN-CONTROLLED FIRMS, ALL INDUSTRIES

	All Innovations		Canadian-Controlled Innovations		Foreign-Controlled Innovations	
Source	No.	%	No.	%	No.	%
External only	77	27	14	12	63	39
Internal R&D	187	66	99	82	88	54
Both	19	7	8	7	11	7
Total	283	100	121	100	162	100

Only 27 per cent of all the reported innovations were primarily based on technology obtained outside the firm, as opposed to technology developed in-house (via internal R&D). In the case of Canadian-controlled firms, only 12 per cent of their innovations utilized externally acquired technology as compared to 39 per cent for foreign-controlled firms' innovations. Thus foreign-controlled firms much more often utilize imported technology than do Canadian firms. On the other hand, over half (54 per cent) of the innovations of the reporting foreign-controlled firms were primarily based on technology developed by the subsidiary in-house.

The primary source of technology was external for 24 per cent of the process innovations of Canadian-controlled firms and only 8 per cent of their product innovations were based primarily on imported technology as compared to 40 per cent for the process and 38 per cent for the product innovations of foreign-controlled firms. Sources of technology for the innovations are discussed in greater detail in Chapter IV, i.e., by firm size, control and industry characteristics.

Expenditure Profiles: Canadian- and Foreign-Controlled Firms

It was found in Chapter III that Canadian-controlled firms, on average, spend relatively more on research and on development in the development of both their product and process innovations. The fact that foreign-controlled firms import technology (primarily, but not exclusively, from parent and affiliated firms abroad) plays an important role in reducing the relative research and development spending components of their total expenditures on major innovations. Table 11 below, sets out the spending profiles of innovations for Canadian- and foreign-controlled firms by source of technology.

In general, the innovation profiles for Canadian- and foreign-controlled firms become more similar when we control for technology source (in-house vs. external). In respect of product innovations based on

Table 11

AVERAGE OF RATIOS OF EXPENDITURE BY STAGE
TO TOTAL EXPENDITURES PER INNOVATION,
BY SOURCE OF TECHNOLOGY

Stage	Technology Obtained Externally		Technology Developed In-House		Partly External and Partly In-House	
			PRODUCT INNOVATIONS (%)			
	Canadian (5)	Foreign (31)	Canadian (69)	Foreign (61)	Canadian (4)	Foreign (0)
Basic Research	7.9	0.9	10.4	6.8	9.6	-
Applied Research	7.9	6.3	16.1	13.3	1.3	-
Development	35.1	43.9	42.3	43.3	53.5	-
(R&D)	(51.0)	(51.0)	(68.8)	(63.5)	(64.5)	(-)
Manufacturing Start-Up	40.1	34.4	22.1	29.1	25.8	-
Marketing Start-Up	8.9	14.5	9.1	7.5	9.7	-
			PROCESS INNOVATIONS (%)			
	Canadian (5)	Foreign (17)	Canadian (14)	Foreign (19)	Canadian (4)	Foreign (8)
Basic Research	0	0	8.1	4.6	6.3	2.5
Applied Research	3.0	7.1	15.0	15.9	20.0	27.2
Development	66.4	19.0	25.4	33.0	26.7	36.0
(R&D)	(69.4)	(26.1)	(48.6)	(53.4)	(52.9)	(65.7)
Manufacturing Start-Up	30.3	71.7	46.2	45.6	43.2	33.4
Marketing Start-Up	0.3	2.1	5.2	1.0	3.9	0.9

externally obtained technology, we find that foreign-controlled firms do relatively less research on these innovations but perform relatively more developmental work than Canadian-controlled firms, with the result that relative R&D spending ratios are the same. On the other hand, for product innovations developed in-house, the research component of foreign-controlled firms remains relatively lower and the manufacturing start-up component relatively higher, but the development components are virtually the same for the two types of firms. Hence controlling for source of technology does not altogether remove the differences between foreign-controlled and Canadian-controlled firms' product innovations, but it does reduce the differences.

In respect of process innovations, when we control for technology source, we obtain more interesting results. Process innovations of Canadian-controlled firms which are based on external technology have a very different profile than those of foriegn-controlled firms. Research and development spending is a very small component of total expenditures on these innovations by foreign-controlled firms; manufacturing start-up costs alone represent 72 per cent of total costs. In fact, for 10 out of the 17 innovations in question, manufacturing start-up costs were over 90 per cent of the total costs of the innovations. This stands in contrast to their Canadian-controlled counterparts where R&D spending represents 69 per cent of the total cost of introducing process innovations. In respect of innovations based on imported technology, then, foreign-controlled firms perform relatively significant amounts of R&D work on product innovations but only small amounts on process innovations.

For process innovations based on technology developed in-house, the profiles of spending by foreign- and Canadian-controlled firms are again fairly similar. Foreign-controlled firms spend a little less in relative terms on basic research for these innovations but a little more on developmental work than their Canadian-controlled counterparts. Finally, for process innovations requiring both imported technology and internally generated technology, foreign-controlled firms spend a little more on both research and development in relative terms than do Canadian-controlled firms (though again they spend a little less on basic research).

Therefore, when we control both for source of technology and for type of innovation (product vs. process), the tendency for foreign-controlled firms to spend relatively less on R&D is greatly reduced and in some cases disappears, except in the case of process innovations based on imported technology. In addition, as shown in Chapter III, the R&D expenditures component of innovations tends to fall with the size of the total expenditures on the innovations (see Table 5, Chapter III). This is because innovations requiring expenditures in excess of $1 million require relatively heavy manufacturing start-up expenditures. When we consider that only 16 per cent of the 101 innovations by Canadian-controlled firms required expenditures in excess of $1 million as compared to 31 per cent for the 136 innovations of foreign-controlled firms, it is clear that when these two types of innovations are controlled in addition for differences in the size (total cost) of the innovations, most of the remaining differences in respect of R&D spending proportions disappear.

In fact, when the innovations of foreign- and Canadian-controlled firms are analysed by type of innovation, by source of technology, and by size of innovation, a tendency emerges for the R&D component of process innovations based on in-house technology to be relatively greater for foreign-controlled firms. In respect of product innovations based on in-house technology, foreign-controlled firms also have a relatively larger R&D component with respect to large innovations (innovations in excess of $260,000) but a smaller R&D component for smaller innovations. For product innovations based on imported technology, the innovation spending profiles of the two types of firm are very similar. However, with regard to process innovations based on imported technology, the strong tendency for the innovations of foreign-controlled firms to have a negligible R&D spending component persists. The results of this last exercise are not presented in tabular form because when controlled for type and size of innovation, origin of control of the innovating firm and source of technology simultaneously, the number of cases becomes very small and some of the ratios become rather unstable.

In summary, we have found that when foreign-controlled firms import the technology for their innovations, the research and development spending component in respect of such innovations declines significantly. This is particularly true in the case of process innovations. It appears that foreign-controlled firms can and do import process innovations without having to engage in any significant development spending in relative terms. On the other hand, product innovations based on imported technology still require applied research and significant amounts of developmental work even in relative terms. When we take into account the source of the technology and the size of the innovation, the tendency for foreign-controlled firms to spend relatively less on R&D than Canadian-controlled firms disappears, except in the case of imported process innovations. Interestingly enough, throughout all of the above exercises, one significant difference between foreign- and Canadian-controlled firms' innovations persists -- foreign-controlled firms always spend significantly less in relative terms on basic research than do their Canadian-controlled counterparts in developing their major innovations. This, no doubt, reflects the fact that regardless of the source of technology for their innovations, foreign-controlled firms have access to basic research results of their parents or affiliates and do not attempt to reproduce this basic research in Canada.

Quite aside from the issue of the relative spending profiles of foreign- and Canadian-controlled firms by stage of the innovation and technological change process, the fact remains that in absolute terms, foreign-controlled firms spend significantly more on their major innovations, on average, for every stage of the innovation process except for basic research spending on product innovations (see Table 12 below). This largely reflects the fact that the reporting foreign-controlled firms are, on average, so much larger than the Canadian-controlled firms.

Table 12

AVERAGE EXPENDITURES ON INNOVATIONS BY STAGE:
CANADIAN- VS. FOREIGN-CONTROLLED FIRMS

Source	All Innovations		Product Innovations		Process Innovations	
	Canadian-Controlled (100)	Foreign-Controlled (134)	Canadian-Controlled (78)	Foreign-Controlled (91)	Canadian-Controlled (22)	Foreign-Controlled (43)
			-- ($000)--			
Basic Research	36	113	39	24	28	302
Applied Research	68	268	63	96	86	634
Development	292	1,296	187	416	660	3,157
(R&D)	(396)	(1,678)	(288)	(536)	(780)	(4,093)
Manufacturing Start-Up	283	2,386	216	404	518	6,581
Marketing Start-Up	28	119	28	52	32	261
Total*	708	4,183	532	991	1,329	10,936

* Median Total Expenditures for the innovations of Canadian-controlled firms are $165,000 vs. a median value of $380,000 for foreign-controlled firms' innovations. Median total expenditures for product innovations of Canadian-controlled and foreign-controlled firms were $165,000 and $300,000, respectively, while for process innovations the median values are $117,000 for Canadian-controlled firms' innovations vs. $990,000 for those of foreign-controlled firms.

Costs of Imported Technology

In the survey, we collected data on the level of payments being made for externally acquired technology. There were 96 innovations involving imported technology, and we received information concerning payments for 74 of these. However, of the 74 innovations, 34 did not involve any specific payment for the technology. There were 15 Canadian-controlled innovations reported, of which 4 involved zero payments (received the technology from an affiliated firm or a public research body). In addition, 59 foreign-controlled firms responded, 30 of which reported zero payments. Most of the transfers to foreign-controlled firms (70 per cent) were intracorporate MNE transfers, and in over half of these transfers no separate payment was made for the specific technology.

We have the impression from these data and our interviews that in the majority of cases, members of multinational enterprises draw freely on technology pools (often centralized) to which they all contribute, and that payments for such access are made yearly under a master agreement, with members paying according to their proportions of sales or assets relative to those of the MNE in total. However, we did notice a tendency for the subsidiaries of MNEs to more often enter into specific licensing agreements with their parents on technology transfers in recent years. In addition, where the parents performed very specific research for a particular subsidiary, the subsidiary is normally charged for this work, but might not be if the research is of more general applicability. Also, smaller subsidiaries of foreign firms seem more often to have completely free access to the research and development findings of parent or affiliated firms. Finally, all the foreign subsidiaries stressed the completeness of their access to the technology of parents and affiliates, the vast costs the generation of the technology pools entailed, and the complete inability of the subsidiary to match such spending on their own. The subsidiaries were all of the view that the value to them of the access to the technology pools far exceeded the payments they made for this access, regardless of the form of the payments.

Although wo do not have much data on payments for imported technology, we can examine the average costs of the technology for those innovations for which we do have such information (40 innovations). The technology imports can be split between product and process technologies. Of the 40 innovations for which we have payments data, 27 are product innovations and 13 are process innovations; 11 of the technology imports are by Canadian-controlled firms as compared to 29 by foreign-controlled firms. The following table sets out the mean and median payments for the technologies through to 1978.

Table 13

AVERAGE PAYMENTS FOR IMPORTED TECHNOLOGY

Type of Innovation	Mean	Median
	($000's)	
Product Innovations (27)	298	40
Process Innovations (13)	2,140	426
Canadian-Controlled: (11)	72	40
Product (9)	77	40
Process (2)	48	40
Foreign-Controlled: (29)	1,210	233
Product (18)	409	50
Process (11)	2,521	889

Median payments for product innovation technology do not much differ between foreign- and Canadian-controlled firms, although the mean value for foreign-controlled firms is much higher. Both the mean and median values of payments for process technologies are orders of magnitude higher for foreign-controlled firms -- indicating the importation of very significant process technologies on their part.

The information we have on these payments is clearly insufficient to support any extended analysis or firm conclusions on costs of imported technologies. However, as an experiment, we added the technology payments reported to the R&D component of the expenditure profiles for these innovations. The addition of these payments to the expenditure profiles of the Canadian-controlled firms' innovations had virtually no effect on the profiles because the payments were so small relative to the total costs of the innovations. When the payments of foreign-controlled firms were added to the R&D components of their relevant innovations, the R&D components of both product and process innovations increased sharply. For product innovations, the profiles became quite similar to the spending profiles for innovations developed in-house. For process innovations, the R&D component was still a little lower, and the manufacturing start-up component a little higher than for process innovations developed in-house. But, in general, for the few innovations for which we had information, the addition of payments for the technology to the spending profiles of the foreign-controlled firms' innovations produced expenditure profiles similar to those of innovations based on technologies developed in-house. Of course, as stressed above, 30 of the 59 innovations of foreign-controlled firms on which we have technology payments information indicated zero payments (i.e., they either made no payments to the parent for the technology, or their payments were part of non-specific payments made to their parents on an annual basis).

An Analysis of the Performance of Innovations of Canadian- and Foreign-Controlled Firms

There are a number of tests which can be run to determine whether there are differences between the innovations of Canadian- and foreign-controlled firms in terms of the nature and performance of the innovations being produced. For example, the success of a product innovation can be judged to a degree by the sales it generates -- i.e., how well it succeeds in the marketplace. The median sales value (sales of the product innovation in 1978) for the product innovations of Canadian-controlled firms was $500 thousand as compared to $1.2 million for foreign-controlled firms. To a large extent, this difference reflects the fact that innovations by foreign-controlled firms are considerably larger than those of their Canadian-controlled counterparts. However, the median sales value of the product innovations in 1978 divided by the median total expenditure on the product innovations of Canadian-controlled firms is $3.00 as compared to $4.00 for foreign-controlled firms. Thus, the average sales value in 1978 per dollar spent on product innovations is higher for foreign-controlled firms. The median sales value of the different types of innovations are set out in the table below. In respect of innovations based on technologies generated in-house and those based on externally acquired technology, there is not much difference between median sales values.

Table 14

SALES OF PRODUCT INNOVATIONS PER INNOVATION IN 1978

Type	No. of Innovations	Median Sales Value ($'000)
All Product Innovations	145	995
Product Innovations of Canadian-Controlled Firms	60	500
Product Innovations of Foreign-Controlled Firms	85	1,200
Product Innovations based on External Technology	35	939
Product Innovations based on In-House Technology	101	980

When median sales values are further broken down as to size of firm and origin of control, it can be seen in Table 15 that the tendency for the median sales values of the product innovations of foreign-controlled firms to exceed those of comparably sized Canadian-controlled firms persists, except in respect of the very largest innovations.

Table 15

SALES OF PRODUCT INNOVATIONS PER INNOVATION IN 1978: CANADIAN-CONTROLLED AND FOREIGN-CONTROLLED FIRMS BY FIRM SIZE

Size/Employees in Field	All Innovations		Canadian-Controlled		Foreign-Controlled	
	No.	Med.Sales Value ($000)	No.	Med.Sales Value ($000)	No.	Med.Sales Value ($000)
50 or less	41	251	29	226	12	250
100 or less	67	425	39	300	28	750
200 or less	90	520	47	397	43	926
500 or less	118	750	50	400	68	1,000
Over 500	22	4,200	6	4,600	16	4,000

Another comparison of the impact of innovations relates to the effect the innovation has on the skill requirements of the work force. We have found that most innovations resulted in raised skill requirements. Furthermore, there is no significant difference between Canadian- and foreign-controlled firms' innovations in this respect. Labour force skill requirements were raised in the case of 72 per cent of the innovations of Canadian-controlled firms and for 71 per cent of the innovations of foreign-controlled firms.

Two more dynamic issues of importance relate to the exportability of product innovations developed in Canada and the issue of whether or not the innovations generate further research and/or development work designed to produce additional innovations (a spin-off effect of the development of major innovations).

In respect of exports, we find that 61 per cent of the 145 product innovations on which we have the relevant information were being exported to some degree in 1978. Of the 62 product innovations of Canadian-controlled firms, 68 per cent were being exported in

Table 16

PERCENTAGE OF PRODUCT INNOVATIONS
ASSOCIATED WITH EXPORT SALES IN 1978

Type	No. of Innovations	% of Innovations with Exports
All Product Innovations	145	61
Product Innovations of Canadian-Controlled Firms	62	68
Product Innovations of Foreign-Controlled Firms	83	57
Product Innovations based on External Technology	35	43
Product Innovations based on In-House Technology	109	67

1978 as compared to 57 per cent for the 83 product innovations of foreign-controlled firms. The lower percentage of innovations leading to exports by foreign-controlled firms is due to the fact that only 43 per cent of the innovations which were based on imported technology were being exported in 1978 as compared to 67 per cent for innovations where the technology was developed in-house. To some extent, this reflects the fact that transferred technologies, particularly those transferred on an intracorporate basis, show a tendency to be associated with the placing of restrictions on the firm acquiring the technology.

It should be noted that many of the product innovations dealt with were developed during the 1960s and may well have passed their peak sales period and become more or less obsolete. Therefore, in Table 17 these percentages are recalculated just for innovations introduced after 1970 (i.e., 1971-78). As can be seen from the table, the results change very little.

Table 17

PERCENTAGE OF PRODUCT INNOVATIONS INTRODUCED DURING THE 1971-78 PERIOD ASSOCIATED WITH EXPORT SALES IN 1978

Type	No. of Innovations	% of Innovations with Exports
All Product Innovations	98	62
Product Innovations of Canadian-Controlled Firms	53	68
Product Innovations of Foreign-Controlled Firms	45	56
Product Innovations based on External Technology	14	36
Product Innovations based on In-House Technology	83	66

We can also compare the percentages of the sales of product innovations which were being exported in 1978. The table below sets out the mean and median export percentages for the different types of innovations, showing the average percentages exported for those innovations being exported in 1978 (i.e., zero export cases are excluded). Here we find little difference between the innovations of Canadian- and foreign-controlled firms. Also, in the relatively few cases where product innovations based on external technology are exported, the percentage exported is very low on average.

Table 18

AVERAGE PERCENTAGES OF SALES OF PRODUCT INNOVATIONS EXPORTED IN 1978

Type	No. of Innovations	Mean Export %'s	Median Export %'s
All Product Innovations	89	51	52
Product Innovations of Canadian-Controlled Firms	42	52	50
Product Innovations of Foreign-Controlled Firms	47	50	50
Product Innovations Based on External Technology	15	25	4
Product Innovations Based on In-House Technology	73	56	64

Finally, we can also examine the average values of product innovation exports in 1978 (Table 19). As above, these are the average values of product innovation exports in 1978 in respect of those product innovations which were being exported in 1978. The mean value of exports of the product innovations of Canadian-controlled firms in 1978 was roughly $3 million as compared to a value of $2.6 million for foreign-controlled firms. However, when we examine the median values of these exports, we find the value for foreign-controlled firms, at $581 thousand, is considerably greater than that for product innovations of Canadian-controlled firms ($252 thousand). There are 5 Canadian product innovations being exported in 1978 with export values in excess of $10 million as compared to only one such product innovation by a foreign-controlled firm. Thus, in general, export values tend to be higher for foreign-controlled firms but a small number of product innovation exports of Canadian-controlled firms are extremely large relative to those of foreign-controlled firms.

Table 19

AVERAGE VALUES OF EXPORTS OF PRODUCT INNOVATIONS IN 1978

Type	No. of Innovations	Value of Exports in 1978 Mean	Median
		($'000)	
All Product Innovations	89	2,754	400
Product Innovations of Canadian-Controlled Firms	42	2,983	252
Product Innovations of Foreign-Controlled Firms	47	2,550	581
Product Innovations Based on External Technology	15	1,486	170
Product Innovations Based on In-House Technology	73	3,033	470

A final test of the innovations of the two types of firms relates to the extent to which the research and development work performed in the course of producing the reported innovations led to further R&D to develop additional innovations. A very high proportion of innovations led to such spin-offs and firms have stressed that in many cases the spin-off innovations were or had the potential to be at least, if not more, significant than the reported innovations. Some of the reported innovations themselves were linked innovations -- i.e., a firm often reported innovations which were themselves spin-offs from the other reported innovations by the firm. Clearly this is an important dynamic consideration. In Table 20 are set out the proportions of reported innovations which led to spin-off innovations, by control of firm and primary source of technology. The performance of the innovations of Canadian-controlled firms is slightly better than that of the foreign-controlled firms in respect of spin-offs. However, in this case the significant difference in performance is between innovations based on imported technology and innovations where the technology was developed in-house. Spin-off innovations resulted from 76 per cent of the innovations based on technology developed in-house but from only 55 per cent of the innovations based on externally acquired technology.

Table 20

PERCENTAGE OF INNOVATIONS LEADING TO SPIN-OFFS

Type	No. of Innovations	% Leading to Spin-Offs
All Innovations	278	70
Innovations of Canadian-Controlled Firms	118	74
Innovations of Foreign-Controlled Firms	160	68
Innovations Based On External Technology	76	55
Innovations based on In-House Technology	183	76

The general conclusion we derive from these tests is that, based on the sort of performance indicators available to us, performance of the innovations of the Canadian-controlled firms is slightly superior to that of the innovations of the foreign-controlled firms, because the performance indicators for innovations developed from technology obtained externally are inferior to those based on technology developed in-house. The exception is in terms of sales values of product innovations where foreign-controlled firms perform better. In fact, when only innovations which are based on technology developed in-house are considered, the performance of the innovations of foreign-controlled firms is the same or superior to that of Canadian-controlled firms' innovations. For example, the percentage of product innovations that were developed in-house which were being exported in 1978 was virtually the same (67 per cent) for foreign-controlled firms compared to Canadian-controlled firms. In addition, the mean and median percentages of sales being exported are considerably higher for product innovations based on technology developed in-house by foreign-controlled firms than for any other set of innovations. The mean and median figures for this type of innovation for foreign-controlled firms are 61 and 75 per cent, respectively. Also, a high percentage (77 per cent) of the innovations based on internally developed technology by foreign-controlled firms led to spin-offs.

These findings suggest that, overall, foreign-controlled firms are playing a larger role in terms of import replacement in Canada than in terms of exportation,* because of the larger role imported technology plays in the innovations of foreign-controlled firms, reducing their exportability. We will return to this subject in Chapter IX dealing with the changing nature of innovations over time.

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*It should be pointed out that the discussion of exportability and sales values of innovations is in terms of product innovations only, and foreign-controlled firms have been found to be playing a larger role in Canada in respect of process innovations. The tests could not be run for process innovations because first we did not collect such information and second, because the tests are not really amenable to process innovations.

Summary

Canadian-controlled firms comprised 48 per cent of all reporting firms, the balance being made up of foreign-controlled firms (the majority of which were U.S.-controlled).

On average, the foreign-controlled firms are considerably larger than the Canadian-controlled. As a result, foreign-controlled firms represent 75 per cent of all reporting firms with 500 or more employees in the field, while Canadian-controlled firms represent 64 per cent of all reporting firms with 100 or less employees.

Reporting foreign-controlled firms account for 70 per cent of all process innovations because of their dominant position in the process-oriented industries in the survey.

For product innovations, 72 per cent of those of Canadian-controlled firms were new (as opposed to product improvements) as compared to 60 per cent for foreign-controlled firms. The situation is reversed for process innovations -- 51 per cent of those of foreign-controlled firms were new processes as compared to 45 per cent for Canadian-controlled firms.

The foreign-controlled firms devoted longer periods of time to the development of both product and process innovations, the difference being greater for processes.

The foreign-controlled firms had longer pay-back periods than did Canadian-controlled firms.

A larger proportion of the innovations of Canadian-controlled firms were originals (world firsts) in respect of product innovation than was the case for foreign-controlled firms (62 per cent vs. 48 per cent). However, for process innovations 48 per cent were original innovations

for both Canadian- and foreign-controlled firms. For all innovations, 41 per cent of Canadian-controlled firms' innovations were imitative of innovative developments around the world as compared to 52 per cent for foreign-controlled firms.

In general, Canadian-controlled firms are quicker to imitate product innovations first introduced abroad, while foreign-controlled firms are quicker to imitate process innovations.

Foreign-controlled firms tended to utilize imported technology for their innovations to a much greater extent than did Canadian-controlled firms, but even so, over half (54 per cent) of their reported innovations were based on technology they developed in-house. On the other hand, 82 per cent of the innovations of Canadian-controlled firms were based on technologies developed in-house. Although Canadian-controlled firms were not significant purchasers of product technology, they did obtain technology primarily from outside the firm for 24 per cent of their process innovations.

The foreign-controlled firms tend to spend relatively more on manufacturing start-up and less on research and development in developing and introducing their major innovations, but when we control for both the source of technology and the larger size of foreign-controlled firms' innovations this tendency disappears in general.

Innovations of foreign-controlled firms based on imported technology have significantly smaller R&D components than other innovations, particularly in the case of imported process innovations.

The foreign-controlled firms always spent relatively less on basic research than their Canadian counterparts, no doubt reflecting the access of foreign-controlled firms to the basic research findings of their parents.

Average expenditures on innovations by foreign-controlled firms were significantly larger in absolute terms than those of Canadian-controlled firms in respect of both total expenditures and expenditures at each stage of the innovation and technological change process, with the exception of basic research spending on product innovations which is higher for the innovations of Canadian-controlled firms.

Foreign-controlled firms' innovations tend to have larger sales values than those of Canadian-controlled firms, even per dollar of expenditure on the innovation.

The product innovations of foreign-controlled firms exhibit inferior performance in terms of exportation relative to those of Canadian-controlled firms, though on average, where exports do occur the median values of exports of foreign-controlled firms exceed those of Canadian-controlled firms. Exports in 1978 were associated with 68 per cent of the product innovations of Canadian-controlled firms but only 57 per cent of those of foreign-controlled firms. Differences between the two types of firms arise because of the extremely poor export performance of product innovations based on imported technology. Finally, the percentage of innovations leading to spin-off R&D and further innovations was slightly higher for Canadian-controlled firms, and this too resulted from the relatively poor performance of innovations based on imported technology. In fact, the export and spin-off performance indicators for the innovations of foreign-controlled firms based on technologies developed in-house were either as good or better than those for all other sets of innovations.

Chapter VI

TECHNOLOGICAL CHANGE IN SMALL AND LARGE FIRMS

The role of small firms in the innovation process has been examined in a number of countries. Studies in the United States and the United Kingdom have found that the small firm plays an extremely important role in the innovation process in a large number of industries. This topic is of particular concern in Canada since we have a large and vigorous small business community.

Evidence regarding the relationship between firm size and innovation is mixed. Certainly small firms lack the resources to undertake the research and development work and post-R&D expenses to develop and introduce large radical innovations. But we find small firms in Canada are, in fact, very innovative firms.* Small firms (100 or fewer employees) represent 52 per cent of all firms reporting innovations in our survey. These firms account for 48 per cent of all reported product innovations and 29 per cent of all reported process innovations -- an indication of their comparative advantage in product innovation. Studies have shown that small firms play an important role in the technological change process which is distinct from that of the large firm. The purpose of this chapter is to try to isolate some of the differences in the nature and characteristics of the innovations of small firms as compared to large firms.

In the following sections, small firms are compared to large in terms of types of innovations and the resources devoted to the process of technological change in order to identify the relative strengths and

*The concept of a "small firm" is necessarily vague and ill-defined. What constitutes a small firm will vary significantly by industry and by type of issue being addressed, i.e., technological, financial, managerial, organizational, etc. For purposes of our initial analysis, we use an employment-based distribution of firms ranging from a size of "50 employees or less" in the field (industry) in question to a "more than 500 employees" size classification.

weaknesses of the two types of firms. Where possible, further comparisons are made as to control of firms since, in many instances, Canadian- and foreign-controlled firms in the same size categories exhibit quite different characteristics.

As mentioned above, small firms are well represented in our population of reporting firms. While small firms (100 or less employees in the field in question) represent 52 per cent of all reporting firms, very large firms (over 500 employees) represent only 15 per cent. Table 1 sets out the size distribution of reporting firms by industry.

Table 1

REPORTING FIRMS BY SIZE CATEGORY
AS A PERCENTAGE OF TOTAL REPORTING FIRMS IN THE INDUSTRY

	Number of Employees in Field							
	0-50		51-100		101-500		Over 500	
Industry	No.	%	No.	%	No.	%	No.	%
Telecommunications Equipment and Components	31	49	12	19	17	27	3	5
Electrical Industrial Equipment	19	39	4	8	20	41	6	12
Plastics Compounds and Synthetic Resins	4	20	5	25	9	45	2	10
Smelting and Refining	3	23	1	8	4	31	5	38
Crude Petroleum Production	3	20	2	13	4	27	6	40
All Firms*	61	37	24	15	54	34	24	15

*Includes three firms which were not classified to a specific industry.

The telecommunications equipment and components industry has the largest proportion of small firms (68 per cent of the reporting firms had 100 or less employees in the field). At the other extreme, crude petroleum production and smelting and refining have the largest proportion of very large firms. The industry differences, to a large extent, reflect differences in the technologies of the industries.

Types of Innovations: Small vs. Large Firms

For all innovations taken together, small firms tend to be more product innovation oriented and large firms more process-oriented. For example, only 21 per cent of the innovations of small firms (100 or less employees) were process innovations as compared to 54 per cent for the very large firms. As a result, firms with more than 500 employees (15 per cent of all reporting firms) account for 35 per cent of all process innovations but only 12 per cent of all product innovations.

Table 2

PRODUCT VS. PROCESS INNOVATIONS, BY SIZE OF FIRM

No. of Employees	No. of Product Innovations	No. of Process Innovations	Process Innovations as % of Total
0-50	60	17	22
51-100	32	6	16
101-200	33	12	27
201-500	43	14	25
More than 500	25	29	54
All Innovations	193	78	29

The relative product/process orientation of small and large firms shows some variation at the industry level (Table 3). Larger firms in the telecommunications equipment and components and plastics compounds and synthetic resins industries are clearly more process innovation oriented than are small firms. Very few firms of any size produce process innovations in the electrical industrial equipment industry, and in crude petroleum production, almost all of the reported innovations are process innovations. In the smelting and refining industry, large firms are actually more product-oriented than are small firms, a reflection of the fact that the large smelting and refining firms are more diversified in terms of their overall activities.

Table 3

PRODUCT VS. PROCESS INNOVATIONS, BY FIRM SIZE AND INDUSTRY

No. of Employees in the Field	No. of Product Innovations	No. of Process Innovations	Process Innovations as % of Total
1. Telecommunications Equipment and Components:			
0-50	36	3	8
51-100	20	0	0
101-200	19	3	14
201-500	13	0	0
More than 500	6	4	40
2. Electrical Industrial Equipment:			
0-50	18	3	14
51-100	6	0	0
101-200	10	1	9
201-500	15	1	6
More than 500	10	1	9
3. Plastics Compounds and Synthetic Resins:			
0-50	5	1	17
51-100	6	2	25
101-200	4	5	56
201-500	9	2	18
More than 500	2	2	50
4. Smelting and Refining:			
0-50	0	5	100
51-100	0	1	100
101-200	0	0	0
201-500	3	10	77
More than 500	4	9	69
5. Crude Petroleum Production:			
0-50	0	5	100
51-100	0	3	100
101-200	0	3	100
201-500	3	1	25
More than 500	0	13	100

The distribution of new versus improved innovations shows no tendency to change regularly with firm size (Table 4). With the exception of medium-sized firms where the proportion of new innovations is the same or higher for foreign-controlled firms, Canadian-controlled firms show a tendency to produce higher proportions of new innovations than do foreign-controlled firms.

Table 4

PROPORTION OF NEW AND IMPROVED INNOVATIONS, BY SIZE OF FIRM AND CONTROL, ALL INDUSTRIES

	Number of Employees in Field									
	0-50		51-100		101-200		201-500		Over 500	
	No.	%	No.	%	No.	%	No.	%	No.	%
All Innovations:										
New	50	65	20	53	28	62	40	70	28	52
Improved	27	35	18	47	17	38	17	30	26	48
Canadian-Controlled:										
New	37	73	10	53	8	53	15	83	7	58
Improved	14	27	9	47	7	47	3	17	5	42
Foreign-Controlled:										
New	13	50	10	53	20	67	25	64	21	50
Improved	13	50	9	47	10	33	14	36	21	50

There is also no clear trend with firm size in the propensity of firms to produce original innovations rather than imitations (Table 5). However, when firm size is further characterized by control and industry information, it becomes apparent that differences exist between the two types of firms. Very small and larger Canadian-controlled firms tend to produce a higher proportion of original innovations than do foreign-controlled firms of these sizes. On the other hand, for medium-sized firms (51-200 employees), this tendency is reversed. As we have seen earlier, the acquisition of technology for innovations from a source external to the firm explains the general tendency for foreign-controlled firms to produce higher proportions of imitative innovations.

Table 5

PROPORTION OF ORIGINAL INNOVATIONS AND IMITATIONS, BY SIZE OF FIRM AND CONTROL, ALL INDUSTRIES

	Number of Employees in Field									
	0-50		51-100		101-200		201-500		Over 500	
Type	No.	%	No.	%	No.	%	No.	%	No.	%
All Innovations:										
Original Innovations	36	47	28	76	20	44	29	52	27	50
Imitations	41	53	9	24	25	56	27	48	27	50
Canadian-Controlled:										
Original Innovations	26	51	14	74	6	40	12	71	8	67
Imitations	25	49	5	26	9	60	5	29	4	33
Foreign-Controlled:										
Original Innovations	10	38	14	78	14	47	17	44	19	45
Imitations	16	62	4	22	16	53	22	56	23	55

At the industry level, there is still no clear trend in the propensity to produce original innovations as firm size alters (Table 6). The smallest firms (50 or less employees) generally tend to produce smaller proportions of original innovations than the large firms (over 200 employees) in all industries. The single exception is the telecommunications equipment and components industry where the very small firms are producing a high proportion of originals and large firms a low proportion, partly as a result of the tendency of large foreign-controlled firms to produce imitative innovations; in contrast, Canadian-controlled telecommunications equipment firms of all sizes produce a consistently high proportion of originals.

Table 6

PROPORTION OF ORIGINAL INNOVATIONS AND IMITATIONS, BY SIZE OF FIRM AND INDUSTRY

	Number of Employees in Field									
	0-50		51-100		101-200		201-500		Over 500	
Type	No.	%	No.	%	No.	%	No.	%	No.	%
Telecommunications Equipment and Components:										
Original Innovations	24	62	17	90	11	50	8	67	3	30
Imitations	15	38	2	10	11	50	4	33	7	70
Electrical Industrial Equipment:										
Original Innovations	8	38	3	50	4	36	9	56	5	46
Imitations	13	62	3	50	7	64	7	44	6	54
Plastics Compounds and Synthetic Resins:										
Original Innovations	2	33	5	62	2	22	4	36	2	50
Imitations	4	67	3	38	7	78	7	64	2	50
Smelting and Refining:										
Original Innovations	0	0	1	100	0	0	5	39	8	61
Imitations	5	100	0	0	0	0	8	61	5	39
Crude Petroleum Production:										
Original Innovations	2	40	2	67	3	100	3	75	7	54
Imitations	3	60	1	33	0	0	1	25	6	46

Other Basic Characteristics of Innovations: Small vs. Large Firms

The amount of time firms have devoted to developing their reported innovations lengthens as firm size increases. The median time devoted to developing and launching innovations in smaller firms (less than 100 employees) is 1½ years as compared to 2½ years for firms with more than 500 employees (Table 7).

Table 7

COMMERCIALIZATION PERIOD, PRODUCT AND PROCESS INNOVATIONS, BY SIZE OF FIRM, ALL INDUSTRIES

Number of Employees in Field	Product Innovations			Process Innovations			All Innovations		
	No.	Mean	Median	No.	Mean	Median	No.	Mean	Median
				- Months -					
0-50	59	15	12	16	15	12	75	15	12
51-100	31	24	18	6	22	24	37	24	18
101-200	33	20	14	12	30	24	45	22	18
201-500	41	23	18	13	28	24	54	24	20
More than 500	24	32	24	29	44	30	53	39	30
All Innovations*	196	21	15	79	30	24	275	24	18

*The sum across size categories does not always equal the figure given for all innovations since, in some cases, no data were provided regarding number of employees in the field.

This difference across firm size holds for both products and processes. In fact, the commercialization period doubles in length for products and triples in length for processes when small firms are compared to large firms. For small firms -- those employing 100 or fewer employees -- there is no significant difference between product and process periods, both requiring about 1½ years to commercialize. It is only at firm sizes above 100 employees that process commercialization periods begin to greatly exceed those for products. The difference between the two types of innovations is most marked among very large firms (over 500 employees) where product commercialization periods average 2½ years, while for processes the length of time required for commercialization is about 3½ years. It appears that resource limitations facing small firms limit the amount of time they can devote to development of their innovations, be they product or process.

Little difference exists between Canadian- and foreign-controlled firms across size groups with regard to product commercialization periods (Table 8). Canadian-controlled firms show a tendency to devote slightly longer periods of time to the development of their product innovations. However, foreign-controlled firms generally devote considerably longer periods to commercializing process innovations than do similarly sized Canadian-controlled firms. Even for large Canadian-controlled firms, although the mean commercialization period for processes greatly exceeds that for foreign-controlled firms, the median value is considerably shorter -- 18 months compared to 30 months.

Table 8

COMMERCIALIZATION PERIOD, PRODUCT AND PROCESS INNOVATIONS, BY SIZE AND CONTROL OF FIRM

No. of Employees in Field	Product Innovations			Process Innovations			All Innovations		
	No.	Mean	Median	No.	Mean	Median	No.	Mean	Median
		- Months-			- Months -			- Months -	
Canadian-Controlled:									
0-50	44	16	12	6	14	12	50	16	12
51-100	14	20	18	4	17	18	18	19	18
101-200	13	20	14	2	24	18	15	21	16
201-500	13	25	12	5	18	18	18	23	12
More than 500	7	30	24	5	56	18	12	41	24
Foreign-Controlled:									
0-50	15	12	10	10	17	12	25	14	12
51-100	17	28	15	2	33	24	19	28	21
101-200	20	20	12	10	31	24	30	23	18
201-500	28	22	18	8	34	30	36	24	20
More than 500	17	33	27	24	41	30	41	38	30

These results reinforce the findings discussed in Chapter V. Foreign-controlled firms are more dominant in respect of process innovations in general, and spend more time developing their process innovations. What is surprising is that small Canadian-controlled firms in particular and, to a limited extent, larger Canadian-controlled firms, tend to spend a greater length of time commercializing products as compared to processes. This reinforces the general finding that Canadian-controlled firms are more attracted to product innovations.

For firms of different sizes, we can also compare lag rates (the time between the first launch of an innovation in the world and its introduction into the firm in Canada). In general, mean lag rates tend to decline as firm size increases, although the trend is not smooth (Table 9). Small firms exhibit an average lag rate of 8.2 years, while the average lag rate associated with large firms is 7.4 years.

Table 9

LAG RATE, PRODUCT AND PROCESS INNOVATIONS, BY SIZE OF FIRM, ALL INDUSTRIES

Number of Employees in Field	Product Innovations			Process Innovations			All Innovations		
	No.	Mean	Median	No.	Mean	Median	No.	Mean	Median
		- Years -			- Years -			- Years -	
0-50	21	8.6	6.5	12	7.7	3.0	33	8.2	5.5
51-100	7	7.1	7.0	2	4.5	2.0	9	6.6	7.0
101-200	16	8.9	3.0	2	10.5	2.0	18	9.1	3.0
201-500	19	5.4	5.0	7	13.9	6.0	26	7.7	5.0
More than 500	11	7.8	5.0	11	6.9	5.5	22	7.4	5.0

When we examine lag rates separately for product and process innovations by size of firm we obtain some interesting results. Whereas for all innovations lag rates on processes, on average, tend to be longer than those for products, this does not hold for innovations of smaller firms. The smaller firms tend to adopt process innovations more quickly than product innovations, while large firms tend to adopt product innovations a little more quickly than process innovations. Also, large firms tend to adopt product innovations rather more quickly than do smaller firms but they adopt process innovations much more slowly than small firms.

These differences in product and process lag rates between small and large firms are influenced by the different lag rates associated with Canadian- and foreign-controlled firms. The data are not presented here since the number of observations is rather small. However, there is a marked tendency for both small and large Canadian-controlled firms to exhibit lag rates on process innovations which greatly exceed those associated with comparably sized foreign-controlled firms.

The greater speed with which small firms adopt process innovations may reflect differences in the quality and magnitude of the process innovations being adopted by the two types of firms. Lag rates by source of technology and for foreign-controlled and Canadian-controlled firms are discussed in Chapter IV.

Another important issue in respect of both small and large firms is the length of the pay-back period, i.e., the length of time a firm is willing (or able) to wait to recover its R&D investment in an innovation. As can be seen in Table 10, pay-back periods lengthen as firm size increases; the majority of innovations of small firms have a pay-back period of less than 3 years, while only 37 per cent of those of the large firms have pay-back periods of this length. On the other hand, a pay-back period of more than five years is associated with 7 per cent of the innovations reported upon by small firms, but 29 per cent of those associated with large firms. Small firms clearly opt for innovations with short pay-back periods. This is true of both Canadian-controlled and foreign-controlled firms.

Table 10

PAY-BACK PERIOD, BY SIZE AND CONTROL OF FIRM, ALL INNOVATIONS

Number of Employees in Field	Pay-Back Period					
	Less than 3 Years		3-5 Years		More than 5 Years	
	No.	%	No.	%	No.	%
All Innovations						
0-50	47	69.1	16	23.5	5	7.4
51-100	22	62.9	6	17.1	7	20.0
101-200	25	58.1	12	27.9	6	14.0
201-500	23	41.1	24	42.9	9	16.0
More than 500	18	36.7	17	34.7	14	28.6
Canadian-Controlled						
0-50	31	67.4	13	28.3	2	4.3
51-100	13	76.5	3	17.6	1	5.9
101-200	9	60.0	2	13.3	4	26.7
201-500	8	44.4	7	38.9	3	16.7
More than 500	4	40.0	3	30.0	3	30.0
Foreign-Controlled						
0-50	16	72.8	3	13.6	3	13.6
51-100	9	50.0	3	16.7	6	33.3
101-200	16	57.1	10	35.7	2	7.2
201-500	15	39.5	17	44.7	6	16.8
More than 500	14	35.9	14	35.9	11	28.2

Expenditure Profiles of Innovations: Small vs. Large Firms

The costs of innovation and R&D effort within firms have been discussed in detail in Chapters III and V, and so only a few remarks will be made here regarding these costs in relation to firm size.

Looking first at product innovations, it can be seen in Table 11 that research costs as a proportion of total innovation costs decline as firm size increases. Development costs form the largest single component of R&D expenditures for all firm sizes, but is greatest for medium-sized firms. For large firms producing product innovations, manufacturing start-up costs are the second most important component of total costs, whereas small firms spend roughly equal proportions on research and manufacturing start-up. The proportion of costs represented by marketing start-up costs decline with firm size. These differences in expenditure profiles as to firm size are strongly influenced by the size (total cost) of the innovations which, on average, are smaller for the small firms.

Table 11

AVERAGE OF RATIOS OF SPENDING PER STAGE TO TOTAL EXPENDITURES PER INNOVATION BY TYPE OF INNOVATION AND FIRM SIZE, ALL INDUSTRIES

	0-100 (N=78)	101-500 (N=66)	Over 500 (N=21)
		-- (%) --	
Product Innovations			
Basic Research	8.0	8.1	2.4
Applied Research	15.9	8.8	9.2
Development	41.4	47.3	44.0
Manufacturing Start-Up	23.6	27.1	41.4
Marketing Start-Up	11.1	8.7	3.0
Total	100.0	100.0	100.0
		-- (%) --	
Process Innovations	(N=17)	(N=22)	(N=22)
Basic Research	6.4	3.6	1.8
Applied Research	11.2	10.0	20.1
Development	45.8	31.0	19.1
Manufacturing Start-Up	34.4	53.2	57.9
Marketing Start-Up	2.2	2.2	1.1
Total	100.0	100.0	100.0

The distribution of expenditures at each stage in the development of process innovations shows very different characteristics (Table 11). Research costs as a proportion of total costs are greater for small than for medium-sized firms but are greatest for large firms. Expenditures at the development stage form by far the largest proportion of costs for process innovations produced by small firms. This reflects the smaller total costs and the concomitant relatively smaller manufacturing start-up costs of small firms' innovations. For process innovations of medium-sized and large firms, however, the greatest proportions of expenditures are made at the manufacturing start-up stage. Development expenditures are second in importance for medium-sized firms while for large firms these costs rank behind manufacturing start-up and research costs. Marketing start-up costs, of course, are a relatively insignificant component of total innovation expenditures on process innovations for all sizes of firms.

The data demonstrate what a large proportion of the total costs are R&D costs for the innovations of smaller firms. They no doubt represent a real burden to these firms, most of which are not producing large outputs over which the R&D costs can be spread.

Source of Technology for Small and Large Firms*

In terms of primary source of the technology for the innovations, it is very small (0-50 employees) and larger firms (over 200 employees) which most often utilize sources of technology which are external to the firm (Table 12). Sources utilized include intracorporate sources, suppliers, customers, and other unrelated firms. Firms employing 51-200 persons are clearly most reliant upon the development of technology for their innovations through in-house R&D. Much of this internally developed technology, however, is used to produce innovations which imitate product and process innovations already in existence elsewhere, primarily abroad (see Table 5 above).

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* For a discussion of sources of technology by firm size at the industry level, see Chapter IV.

Table 12

PRIMARY SOURCE OF THE INNOVATION'S TECHNOLOGY, BY SIZE OF FIRM, ALL INDUSTRIES

No. of Employees in the Field	External Source		In-House R&D		Both	
	No.	%	No.	%	No.	%
0-50	25	33	48	62	4	5
51-100	6	16	30	79	2	5
101-200	7	16	33	73	5	11
201-500	18	32	36	63	3	5
More than 500	18	33	33	61	3	6

Differences in the rates of utilization of the three primary sources of technology are very marked across firm size and control as is discussed in detail in Chapter IV. Canadian-controlled firms of all sizes rely to a much larger extent than do comparably sized foreign-controlled firms upon the in-house development of the technology for their innovations. The utilization of external sources of technology is very great in the case of small foreign-controlled firms -- 65 per cent of their innovations are based on externally acquired technology, while only 16 per cent of the innovations of small Canadian-controlled firms are based on technology acquired from a source external to the firm (see Table 3, Chapter IV). The innovations of foreign-controlled firms which employ 51-200 workers are based much less frequently on external sources of technology, but for firms employing more than 200 persons the extent of utilization of externally acquired technology increases significantly. For example, the innovations of the very large foreign-controlled firms are based on externally acquired technology in 39 per cent of the cases, while the corresponding figure for very large Canadian-controlled firms is only 17 per cent.

Sources of Funding for Small and Large Firms

There are significant differences in the sources of funds for the reported innovations for firms of different sizes (Table 13). Over half of all major innovations reported were funded 100 per cent internally (i.e., firms did not turn to outside sources for funds specifically in support of the innovations). Larger firms (over 200 employees) were able to finance the largest proportion of their innovations completely. Very small firms (50 employees or less) ranked second in this respect in that 53 per cent of the innovations of these firms were 100 per cent internally funded. This likely reflects the difficulties very small firms face in obtaining external financing.

Table 13

USE OF 100% INTERNAL FUNDING, BY SIZE OF FIRM

Number of Employees in the Field	Number of Innovations	Number Using 100% Internal Funding	% of Total Innovations Using 100% Internal Funding
0-50	74	39	53
51-100	36	15	42
101-200	44	19	43
201-500	55	35	64
More than 500	52	36	69

When broken down further as to origin of control of the firm, it can be seen in Table 14 that the group of firms which is least dependent upon 100 per cent internal funding is medium-sized (51-200 employees) Canadian-controlled firms, followed by small (0-50 employees) Canadian-controlled firms. With the exception of firms employing 201-500 persons, larger proportions of the innovations of foreign-controlled firms are 100 per cent internally funded when compared to similarly sized Canadian-controlled firms.

Table 14

USE OF 100% INTERNAL FUNDING,
BY SIZE OF FIRM AND ORIGIN OF CONTROL

Number of Employees in the Field	No. of Innovations	No. Using 100% Internal Funding	Innovations 100% Internally Funded
			(%)
Canadian-Controlled Firms:			
0-50	50	25	50
51-100	17	5	29
101-200	15	4	27
201-500	17	12	71
More than 500	11	7	64
Foreign-Controlled Firms:			
0-50	24	14	58
51-100	19	10	53
101-200	29	15	52
201-500	38	23	61
More than 500	41	29	71

Small and medium-sized Canadian-controlled firms not only must seek outside funding more often, but must also show a high degree of flexibility in doing so, acquiring funds from a diversified group of financial sources. In Table 15, the various sources of external funding for 100 per cent or less of the cost of the innovation are presented, showing the proportion of small, medium and large Canadian- and foreign-controlled firms which acquire some level of funding from each external source.

For all sizes of firms, regardless of origin of control, the two most frequently used sources of funding (excluding 100 per cent internal) are partial internal (i.e., less than 100 per cent) and government. However, the frequency of use of these sources show differences across firm size and control. Small Canadian-controlled firms more frequently use partial internal funding and government than do small foreign-controlled firms. The same is true of medium-sized Canadian- and foreign-controlled firms. Large firms, regardless of origin of control, all rely to some extent on partial internal funding. All of the large Canadian-controlled firms received some government

Table 15

FREQUENCY OF USE OF SPECIFIC SOURCES OF FUNDS FOR INNOVATION FUNDED IN WHOLE OR IN PART EXTERNALLY, BY SIZE OF FIRM AND ORIGIN OF CONTROL

	Innovations by Canadian-Controlled Firms						Innovations by Foreign-Controlled Firms					
	No. of Employees in the Field						No. of Employees in the Field					
	0-100		101-500		More Than 500		0-100		101-500		More Than 500	
Source of Funding	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
	N=37		N=16		N=4		N=19		N=29		N=12	
Partial Internal*	32	86	10	91	4	100	11	58	24	83	12	100
Parent or Affiliate	3	8	4	36	0	0	7	37	12	41	5	42
Private	4	11	1	9	0	0	0	0	2	7	0	0
Bank	9	24	2	18	0	0	7	37	1	3	1	8
Debenture	0	0	0	0	0	0	0	0	0	0	1	8
Venture Capital Firm Firm	1	3	0	0	0	0	0	0	0	0	0	0
Government	24	65	10	91	4	100	9	47	13	45	6	50
Other	6	16	1	9	0	0	2	11	3	10	3	25

*Innovations involving 100% internal funding are excluded.

funding for their innovations, but only 50 per cent of the large foreign-controlled firms did so. Large Canadian-controlled firms, of which there are only 4 for which funding data are available, used no external funding source other than government.

Looking now at the third most frequently used external source of funding, it can also be seen in Table 15 that foreign-controlled firms of all sizes use the parent firm with about the same frequency. Small foreign-controlled firms also acquire funds from banks as do small Canadian-controlled firms, though less frequently. Medium-sized Canadian- and foreign-controlled firms are most similar in their acquisition of funds from external sources, the third most frequently used external source being the parent firm.

Of related importance to the frequency with which firms approach various external sources in order to acquire funds for the development of their innovations is the question of how large a proportion of the total required funds is provided by each source.

For innovations of small foreign-controlled firms, the sources providing the highest average percentage of innovation funds are a parent or affiliate (82 per cent), banks (79 per cent), partial internal (41 per cent), and government (31 per cent) (Table 16). As discussed above in relation to Table 15, these are also the sources which most frequently provided small foreign-controlled firms with funds for their innovations.

In contrast, the sources providing the largest proportion of the funds required to finance the innovations of small Canadian-controlled firms are not the same sources which are most frequently used by these firms. The three sources providing the largest percentage of required funds to Canadian-controlled firms employing 0-100 workers are a parent or affiliate (64 per cent), partial internal (56 per cent), and other sources (50 per cent) (Table 16). The latter include sources such as customers, suppliers, research institutes and other firms involved in joint research. However,

Table 16

AVERAGE PERCENTAGE OF COST OF THE INNOVATION PROVIDED IN WHOLE
OR IN PART BY EXTERNAL SOURCE, BY SIZE OF FIRM AND ORIGIN OF CONTROL

Source of Funding	Innovations by Canadian-Controlled Firms						Innovations by Foreign-Controlled Firms					
	No. of Employees in the Field						No. of Employees in the Field					
	0-100		101-500		More Than 500		0-100		101-500		More Than 500	
	No. of Cases	% Cost Provided	No. of Cases	% Cost Provided	No. of Cases	% Cost Provided	No. of Cases	% Cost Provided	No. of Cases	% Cost Provided	No. of Cases	% Cost Provided
Partial Internal	32	56	10	67	4	56	11	41	24	55	12	56
Parent or Affiliate	3	64	4	94	0	0	7	82	12	72	5	43
Private	4	44	1	66	0	0	0	0	2	52	0	0
Bank	9	43	2	87	0	0	7	79	1	25	1	20
Debenture	0	0	0	0	0	0	0	0	0	0	1	60
Venture Capital Firm	1	25	0	0	0	0	0	0	0	0	0	0
Government	24	38	10	28	4	43	9	31	13	38	6	31
Other	6	50	1	34	0	0	2	22	3	28	3	16

as discussed above, the most frequently used sources of funds by small Canadian-controlled firms are partial internal, government, and banks.

For medium and large Canadian- and foreign-controlled firms, the most frequently used sources of funds tend also to be the sources which provide the greatest average proportions of the total required funds for the innovations. It is apparent, therefore, that it is small Canadian-controlled firms which experience the greatest difficulty in acquiring the capital necessary to finance their innovations since these firms seek funds from a large number of sources, the most frequently used of which provide a relatively small proportion of total funding compared to other types of firms. This finding is further supported by results discussed in Chapter VII where it is found that Canadian-controlled and small firms most frequently cite financial difficulties as significant problems encountered in innovating.

R&D Efforts in Small and Large Firms

The above discussion has focused upon the sources of funds drawn upon over a period of time to finance the generation or adoption of a particular innovation. In this section, the extent of a firm's involvement in the process of research and development is examined, using 1978 data. Since various measures of R&D effort in firms, such as the average number of R&D scientists and engineers employed by firms, and R&D spending per R&D scientist and engineer and per employee in the field are examined in detail in Chapter III, we only recap here the findings reached in that chapter, focusing on the differences between small and large firms.

First, the average number of R&D scientists and engineers tends to increase with firm size. This is true of all firms and of firms in each of the five industries. The smallest firms (50 employees or less) on average employ only 3 R&D scientists and engineers as compared to 39 for firms with 500 or more employees.

Second, the median level of R&D expenditures per R&D scientist and engineer tends also to increase with firm size, though very gradually until firm sizes in excess of 500 employees are reached. For example, firms employing 0-50 employees spent at the median $22,545 per R&D scientist and engineer in 1978 while firms employing 201-500 employees spent $34,833 at the median. For firms with more than 500 employees, the median level of R&D spending per R&D employee in 1978 was $53,903. Both Canadian- and foreign-controlled firms show a tendency to increase the median level of R&D expenditures per R&D scientist and engineer as firm size increases. However, at the industry level this trend is not so clear, although it is generally the case that within industries the smaller firms tended to spend less per R&D scientist and engineer in 1978 than the larger firms.

Third, in terms of R&D intensity, i.e., R&D spending per employee in the field, it is found in Chapter III that small firms tended to be more R&D-intensive in 1978 than larger firms. However, this tendency applies only to Canadian-controlled firms; foreign-controlled firms show no real trend to either increase or decrease in R&D intensity as firm size increases. Again, there is wide interindustry variation in this measure, although it is generally true within industries that smaller firms tended to have higher median levels of R&D spending per employee in the field in 1978 than the larger firms.

Exportation of Product Innovations: Small vs. Large Firms

The final issue to be addressed in respect of the character and performance of small and large firms is that of the degree to which they are active in export markets. Only product innovations are considered and the period covered is 1960-78. Two performance measures are examined: (1) the frequency with which product innovations are exported, and (2) the value of the exports relative to the total sales of the products. Is the exportability of product innovations influenced by firm size?

In Table 17 is set out the proportion of innovations of small and large firms which were being exported in 1978 for those innovations for which we have the relevant information. There is surprisingly little variation in the percentage of innovations being exported by firm size. Even the smallest firms export 51 per cent of their major product innovations. The exception, of course, is the very large firms (over 500 employees) which in 1978 were exporting 86 per cent of the major product innovations which they developed and introduced during the 1960-78 period.

Table 17

PERCENT OF INNOVATIONS BEING EXPORTED IN 1978, BY FIRM SIZE

Firm Size	No. of Innovations	No. of Innovations Exported	% of Innovations Being Exported
(No.of Employees in Field)			
0-50	41	21	51
51-100	26	17	65
101-200	23	12	52
200-500	29	16	55
More than 500	22	19	86

Looking at only those innovations that are being exported, it can be seen in Table 18 that the average percentage of sales of product innovations accounted for by export sales is more variable by firm size. The very small firms tend to have lower average percentages of their total sales of their product innovations exported, and the largest firms now rank second in terms of average export percentages. Nevertheless, for all firm sizes except those having 201-500 employees, the average percentages of sales of product innovations being exported in 1978 is surprisingly high. For those major product innovations that are being exported (61 per cent of total product innovations), a significant dependence on export markets is revealed.

Table 18

AVERAGE PERCENTAGE OF SALES OF PRODUCT INNOVATIONS
EXPORTED IN 1978, BY FIRM SIZE

Number of Employees in Field	No. of Innovations	Exports as % of Total Innovation Sales	
		Mean	Median
		(%)	
0-50	21	51	40
51-100	17	53	60
101-200	12	63	75
201-500	16	33	10
More than 500	19	63	73

The ability of firms to engage in export activity, then, appears to be strongly affected by size considerations. Support for this finding can be found in Chapter VIII where we discuss the nature of the motivations to innovate. Small firms are strongly affected by domestic market factors, specifically, the perception of market gaps or new markets. In other words, they are oriented to filling domestic market niches, whereas larger firms, being more confined by given domestic market shares at least in the short term, turn to international markets.

Consideration of the cost of exporting also plays a role, in that information must be sought about foreign markets, distribution channels developed, and hidden costs covered such as the large information demands associated with customs procedures. In addition, there frequently are delays in payments which represent a significant financial burden for small companies which are heavily dependent upon short-term cash flow. That financial constraints are affecting the ability of small firms to engage in export activities is a conclusion also supported by findings reached in Chapter VII. When asked to list the most significant problem encountered in innovating, small firms relatively most frequently mentioned both marketing and financial problems. Also, government-related problems which include difficulties with government laws and regulations were most frequently mentioned by small firms, though much less often than were marketing and financial problems.

Summary

Most of the firms in the survey (52 per cent) are small in size, employing 100 or fewer people; only 15 per cent of the firms employ more than 500 people. On average, Canadian-controlled firms are much smaller than foreign-controlled firms.

Overall, small firms tend to be product innovation oriented; 79 per cent of their innovations are products. Large firms, on the other hand, are more process innovation oriented, in that 54 per cent of their innovations are of this type. This is generally true of each of the industries with the exception of the smelting and refining industry where small firms are exclusively oriented to process innovations but where large firms produce both product and process innovations.

There are no clear trends with firm size in the propensity to produce new versus improved and original versus imitative innovations. There is only a slight tendency for small and large Canadian-controlled firms to produce higher proportions of both new and original innovations than small and large foreign-controlled firms.

Small Canadian-controlled firms not only produce a large proportion of product innovations, but also spend a greater period of time developing and commercializing them relative to foreign-controlled firms. There is little difference in commercialization period between product and process innovations associated with small Canadian-controlled firms, but for very large Canadian-controlled firms, the median product commercialization period exceeds the median for process innovations.

Small and large foreign-controlled firms, on the other hand, are not only more process-oriented in terms of the numbers of process innovations which they produce, but also spend a longer period of time developing and commercializing these innovations relative to their product innovations. In addition, lag rates in introducing process innovations already developed abroad are shorter for both small and large foreign-controlled firms relative to comparably sized Canadian-controlled firms.

The upgrading of process technology is an activity which improves the internal operations of efficiency of a firm. In contrast, the development of new and improved products is an activity oriented towards the environment external to the firm. Our survey was not designed to study the relationship between productivity and technological change. However, the relatively stronger process-orientation of foreign-controlled firms may be an important factor influencing their generally better productivity performance as found in some recent studies.

Turning now to the more financial aspects of innovation in the small firm, we find that the majority (69 per cent) of the innovations of small firms have pay-back periods of less than 3 years; only 37 per cent of the innovations of large firms have pay-back periods of this length. In contrast, 29 per cent of the innovations of large firms have pay-back periods of over 5 years while only 7 per cent of the innovations of small firms have pay-back periods of this length. The relative proportions of Canadian- and foreign-controlled firms in each category are remarkably similar.

For product innovations, small firms incur by far the largest proportion of their innovation costs at the development stage; research and manufacturing start-up costs rank second. For large firms producing product innovations, development costs also represent the largest proportion of total innovation costs and manufacturing start-up costs rank second, representing only a slightly smaller proportion than the development costs. For large firms' product innovations, development and manufacturing start-up costs together amount to 85 per cent of the cost of the innovations.

For process innovations, development expenditures also form the largest proportion of total innovation costs for small firms. Manufacturing start-up costs rank second and are twice as large in terms of proportions as research costs. In contrast, 58 per cent of the total cost of process innovations are incurred by large firms at the manufacturing start-up stage. Research costs rank second at 22 per cent, while development costs rank third. The importance of research spending by large firms on process innovations may account for a large part of the observed longer development and commercialization period associated with these innovations.

In terms of source of technology, both small and large firms utilize external sources relatively heavily, although for firms of all sizes, the in-house development of technology for innovations is by far the most important primary source of technology. Marked differences are found between firms on the basis of origin of control. The utilization of external sources of technology is very great among small and, to a lesser though still significant extent, among large foreign-controlled firms. Canadian-controlled firms of all sizes, on the other hand, tend to rely to a much larger extent on the in-house development of technology as do medium-sized foreign-controlled firms.

Large firms, regardless of origin of control, show the greatest propensity to fund 100 per cent of the cost of their innovations internally. Small Canadian- and foreign-controlled firms and medium-sized foreign-controlled firms fund more than 50 per cent of their innovations through 100 per cent internal funding; medium-sized Canadian-controlled firms, however, tend to rely upon external sources of funding.

The external sources of funding used by small and medium-sized Canadian-controlled firms are large in number, with no single source providing a very large proportion of the funds required to finance the innovations.

Foreign-controlled firms of all sizes also use a diversity of external sources of funding, the most frequently used of which, however, provide substantial proportions of the funds required for the innovation.

In terms of R&D resources and efforts of firms, small firms understandably tend to have fewer R&D scientists and engineers than do large firms. Small firms also have lower levels of R&D financial resources per R&D scientist and engineer, although there is significant industry variation in this measure. In contrast, there is a general tendency for small firms to be more R&D-intensive than large firms, i.e., to spend more on R&D activities per employee in the field.

Very large firms export significant proportions of their product innovations and, when they do, larger proportions of the total sales of the innovations come from export markets. Nevertheless, over 50 per cent of the innovations of small and medium-sized firms also are exported, although very small firms tend to have lower average percentages of sales of their product innovations coming from exports. It is apparent, therefore, that scale considerations play a role in the ability of firms to export.

Chapter VII

SOME ISSUES RELATING TO THE MANAGEMENT AND IMPACTS OF INNOVATION

This chapter examines a number of issues relevant to the management of innovations and some of the impacts of innovations on firms. Specifically, we discuss factors affecting the firms' decisions to innovate, information sources for innovations, some labour force effects of the innovations, effects of innovations on skill requirements and how these are met by firms, the patenting of major reported innovations, the sale of technology, and problems encountered by firms in innovating. We do not attempt to present a theory of the management of innovations for this would, in reality, amount to a theory of the firm and thus represent a subject considerably broader than the subject matter of the present study.

Factors Affecting the Decision to Innovate

In the course of working toward the development and commercialization of an innovation, there is really never a single "decision to innovate", but rather a series of decisions over time. In the survey, a general probe question was asked about the most important factors in the firm's decisions to develop their innovations -- ranging from responses to foreign and domestic competitors using a similar innovation, through perception of market gaps, to interaction with customers and suppliers. Factors involved in the decision to innovate, by control of firm and type of innovation, are presented in Table 1.

Although for most innovations (57 per cent), respondents perceive themselves as "taking advantage of new technological capabilities", market-related factors are also very frequently cited. Approximately one-third of the innovations were prompted by a desire

Table 2

THE DECISION TO INNOVATE: PROPORTION OF INNOVATIONS FOR WHICH EACH FACTOR IS CITED, BY TYPE OF INNOVATION AND CONTROL

Factor	All Innovations (N=283)	Canadian-Controlled Innovations (N=121)	Foreign-Controlled Innovations (N=162)	Process Innovations (N=82)	Product Innovations (N=201)
			--% --		
Response to foreign competitors using similar innovations	12	17	8	7	14
Response to domestic competitors using similar innovations	11	12	10	7	13
To take advantage of new technological capabilities	57	56	57	56	57
To reduce labour requirements	10	10	10	27	3
To reduce energy requirements	7	7	7	13	4
To reduce capital requirements	5	2	7	10	2
To meet government regulatory requirements	5	3	6	9	3
Perception of new market or gap in existing market	54	66	45	17	69
As a result of pressures from deteriorating profit margins	9	12	7	9	9
To improve quality of the products covered by innovation	22	23	20	21	22
Interaction with your customers	31	30	32	7	41
Interaction with your supplier	2	2	1	1	2
To gain a larger market share	33	36	31	23	37

Note: Columns do not sum to 100% since for each innovation respondents were asked to indicate the three most important factors in their decision to innovate.

to "gain a greater market share", and 54 per cent of the innovations were prompted by a "perception of a new market or a gap in existing markets". The latter factor is cited for 69 per cent of all product innovations, making it the most frequently cited factor in the decision to innovate. For all innovations, the perception of a new market or a gap in existing markets is cited for 66 per cent of the innovations by Canadian-controlled firms, a figure significantly higher than for innovations by foreign-controlled firms (45 per cent). These differences as to origin of control partly reflect the stronger product-orientation of Canadian-controlled firms and, as will be seen further below, size considerations. A third important market-related factor is "interactions with customers", which was cited for 31 per cent of all innovations, rising to 41 per cent for product innovations.

The improvement of the quality of the products covered by the innovation is another important factor in the decision to innovate, being cited in the cases of about one-fifth of the innovations of both Canadian- and foreign-controlled firms and one-fifth of both product and process innovations. That this factor is not cited even more frequently is somewhat surprising, particularly with regard to product innovations. However, when it is considered that quality improvement is a means of achieving other more market-related goals, the relatively small proportion of innovations for which this factor is indicated as being one of the important motivations in the decision to innovate becomes more understandable.

As a group, "the reduction of labour, energy or capital requirements"* is not generally considered to be a significant factor by firms. However, when examined individually, it becomes apparent that the reduction of labour requirements in respect of process innovations is an important motivation, affecting 27 per cent of all such innovations.

Overall, major innovations were not developed and commercialized in response to government regulatory requirements. This factor is most frequently cited in the case of process innovations where it played a

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* The "reduction of material requirements" as a factor in innovation decisions was omitted from the questionnaire when it was printed.

role in the commercialization of 9 per cent of the innovations. The least frequently cited factor in the decision to innovate is"interactions with suppliers", which is cited for 2 per cent or less of all innovations regardless of type of innovation and origin of control of the firm. Thus, in Canada, suppliers are not important motivating factors in the decision to innovate although, as discussed in the following section, they are important sources of information relating to innovations.

In general, there are not great differences in the factors affecting innovation decisions between Canadian- and foreign-controlled firms. The major difference is in the relative importance assigned to the market gap motivation which is greater for Canadian-controlled firms, but which can generally be explained by their smaller average size. In addition, Canadian-controlled firms are more sensitive to competition, as indicated by the fact that 17 per cent of their innovations are in response to innovations of foreign competitors and 12 per cent in response to deteriorating profit margins. The corresponding figures for innovations of foreign-controlled firms are 8 per cent and 7 per cent, respectively. Again, as will be seen below, this is largely a size-related difference. Further differences between innovations of Canadian- and foreign-controlled firms arise out of the relative product/process orientation of the two types of firm.

Table 2 sets out the frequency with which each factor in the decision to innovate is cited by size of the innovating firm. Market-related factors are most important for both small and large firms, although the precise nature of these differs between the two groups. Small firms are oriented towards the filling of market niches, whereas large firms focus to a greater extent upon increasing their market shares. Customers play a significant role in the decision to innovate for smaller firms and, in addition, small firms show a slightly greater sensitivity to the impact of foreign competition. Large firms, on the other hand,

Table 2

THE DECISION TO INNOVATE: PROPORTION OF INNOVATIONS FOR WHICH EACH FACTOR IS CITED, BY SIZE OF FIRM

Factor	Number of Employees in Field 0-50	51-100	101-200	201-500	More Than 500
			-- % --		
Response to foreign competitors using similar innovations	18	8	13	11	9
Response to domestic competitors using similar innovations	14	8	20	11	6
To take advantage of new technological capabilities	58	47	36	63	69
To reduce labour requirements	6	11	9	4	17
To reduce energy requirements	6	5	4	4	13
To reduce capital requirements	4	0	2	9	7
To meet government regulatory requirements	3	8	7	5	4
Perception of new market or gap in existing market	62	58	49	61	35
As a result of pressures from deteriorating profit margins	6	16	9	5	11
To improve quality of the products covered by innovation	25	16	20	28	15
Interaction with your customers	34	34	49	28	15
Interaction with your suppliers	3	5	2	0	0
To gain a greater market share	30	32	38	25	44

Note: Columns do not sum to 100% since for each innovation respondents were asked to indicate the three most important factors in their decisions to innovate.

are more sensitive to internal cost factors, showing a greater tendency than small firms to develop innovations which contribute toward a reduction in labour and energy requirements.

As we would expect, there is considerable inter-industry variation in the relative importance of the different factors affecting the decision to innovate (Table 3). Although the filling of market gaps and increasing of market share are important to firms in all industries, these are most important to telecommunications equipment and components producers who cite these factors for 75 per cent and 40 per cent of their innovations, respectively. Firms in the electrical industrial equipment and plastics compounds and synthetic resins industries also cite these factors relatively more frequently than do firms in the smelting and refining and crude petroleum production industries. Similarly "interactions with customers" is a relatively unimportant factor in the latter two process-oriented industries compared to the relatively more product-oriented industries. Instead, smelting and refining producers and, to a lesser extent, crude petroleum producers, are more oriented towards the reduction of labour requirements.

Although the remaining factors do not have large impacts on firms with regard to the decision to innovate, some of them do exhibit inter-industry variations of interest. The reduction of energy requirements is most frequently cited by firms in the smelting and refining industry which is generally energy-intensive. This industry also is most affected by government regulatory requirements. It is interesting to note that the two industries which are most sensitive to foreign and domestic competition, i.e., the plastics compounds and synthetic resins and electrical industrial equipment industries, also are the two which are most oriented towards improvements in the quality of the products covered by the innovation. In addition, plastics compounds and synthetic resins firms most frequently cite the importance of deteriorating profit margins as a motivating factor in their innovation decisions.

Table 3

THE DECISION TO INNOVATE: PROPORTION OF INNOVATIONS FOR WHICH EACH FACTOR IS CITED, BY INDUSTRY

Factor	All Innovations	Telecommunications Equipment and Components	Electrical Industrial Equipment	Plastics Compounds and Synthetic Resins	Smelting and Refining	Crude Petroleum Production
			-- % --			
Response to foreign competitors using similar innovations	12	8	19	23	3	3
Response to domestic competitors using similar innovations	11	8	15	23	3	10
To take advantage of new technological capabilities	56	56	60	53	48	63
To reduce labour requirements	10	6	13	3	24	13
To reduce energy requirements	7	0	10	10	18	10
To reduce capital requirements	5	2	3	8	9	10
To meet government regulatory requirements	5	0	7	8	9	7
Perception of new market or gap in existing market	54	75	54	53	27	10
As a result of pressure from deteriorating profit margins	9	9	9	18	6	0
To improve quality of the products covered by innovation	22	17	32	28	15	13
Interaction with your customers	31	40	34	40	18	0
Interaction with your suppliers	2	3	0	3	3	0
To gain a greater market share	33	40	32	33	21	20

Note: Columns do not sum to 100% since for each innovation respondents were asked to indicate the three most important factors in their decisions to innovate.

Finally, firms in all industries place great importance upon utilizing new technological capabilities, an obviously important driving force behind innovation. The lack of influence of suppliers on the decision to innovate is pervasive at the industry level.

Information Sources for Innovations

There are surprisingly few studies examining how firms acquire information about potentially useful new technology, given the obvious importance of the subject. Studies of American, Irish and Canadian firms have consistently found that the major information source used by firms for new technology is direct personal contact with personnel in other firms such as suppliers, customers and competitors. They have also found that documentation sources and computerized documentation institutes play insignificant roles in diffusing information. Research institutes supported by these countries were not found to play a large role in affecting the innovation process. These findings are similar to the views expressed by firms in our interviews and some of the findings of our survey.

In the survey, respondents were asked about sources of information utilized in the generation of their innovations. Possible responses involved sources either inside the firm (such as R&D units, production personnel, etc.), or sources outside the firm (the parent firm, suppliers, customers, competitors, etc.). In the following discussion we are particularly interested in the sources by which information entered the firm, and so will focus on outside information sources. Data regarding the relative frequency with which various information sources are used are presented in Table 4.

For process innovations, the most important sources of information are a parent or affiliated firm (cited in 33 per cent of all process innovations), suppliers (cited in 29 per cent of all process innovations), and written sources (cited in 14 per cent of all process innovations). Customers are utilized as information sources for process innovations in only 4 per cent of the cases, and suppliers are used at more than twice the rate with processes as with products. Similarly, the role played by consultants as sources of information is of some significance for process innovations (13 per cent) but not for product (4 per cent). In contrast, the most important sources of information for product innovations are customers, a parent or affiliated firm, and competitors.

Table 4

INFORMATION SOURCES, PRODUCT VS. PROCESS INNOVATIONS

Source	% of All Innovation for Which Source is Cited N = 283	% of All Product Innovation for Which Source is Cited N = 201	% of All Process Innovation for Which Source is Cited N = 82
Outside Source			
Suppliers	17	12	29
Customers	35	48	4
Competitors	13	15	9
Parent or Affiliate	27	24	33
Consultants	7	4	13
Trade Fairs or Associations	2	2	2
Independent Inventor	2	1	4
Government Research Institutes	2	2	2
Universities	2	2	2
Written Sources	10	8	14
Inside Source			
R&D Group or equivalent	70	73	62
Management	30	30	30
Sales Force	12	16	4
Marketing Personnel	24	31	6
Production Personnel	19	11	40

Note: Columns do not sum to 100% since several sources may be cited for a single innovation.

Universities, government institutions, trade fairs and independent inventors are not significantly utilized by the firms for either product or process innovations.

The most frequently used outside information sources across firm control are summarized in Table 5. For innovations of Canadian-controlled firms, the most important information source is customers and for innovations of foreign-controlled firms, a foreign parent or affiliate, followed by customers.

Table 5

MOST FREQUENTLY USED OUTSIDE INFORMATION SOURCES,
BY ORIGIN OF CONTROL

% of All Innovations for Which Source is Cited (N = 283)		% of Canadian-Controlled Innovations for Which Source is Cited (N = 121)		% of Foreign-Controlled Innovations for Which Source is Cited (N = 162)	
Source	%	Source	%	Source	%
Customers	35	Customers	39	Parent or Affiliate	41
Parent or Affiliate	27	Suppliers	20		
		Competitors	16	Customers	33
Suppliers	17	Written Sources	8	Suppliers	15
Competitors	13			Competitors	12

The predominance of customers, both as a source of awareness knowledge of the product innovations and as a source of technical information is not surprising. Normally one thinks of customers as passively articulating demands and manufacturers as surveying groups of customers to obtain information on new product needs, developing a responsive new product idea and then testing it against consumer preferences. This scenario may work well for consumer products, but does not fit the case of industrial product idea generation. Research in the United States supports the findings that user firms (customers) are of great importance in the development of technology by equipment firms in certain industries. In addition, as shown in the above table, foreign-controlled firms have the important parent and affiliate network as an information source.

In Table 6 are summarized the most frequently used outside information sources across firm control for product and process innovations separately. Here a slightly different picture emerges. First, the most frequently utilized information source for product innovations of both Canadian- and foreign-controlled firms is now the customer. Suppliers are utilized as information sources for products by Canadian-controlled firms at about twice the rate as utilized by foreign-controlled firms for which a parent or affiliated firm is of much greater importance. Competitors are utilized at about the same rate for product innovations by both types of firm.

Table 6

MOST FREQUENTLY USED OUTSIDE INFORMATION SOURCES, BY TYPE OF INNOVATION AND ORIGIN OF CONTROL

% of Canadian-Controlled Product Innovations for Which Source is Cited (N=96)		% of Foreign-Controlled Product Innovations for Which Source is Cited (N=105)	
Source	%	Source	%
Customers	47	Customers	50
Suppliers	17	Parent or Affiliate	39
Competitors	16	Competitors	15
Parent or Affiliate	8	Suppliers	8

% of Canadian-Controlled Process Innovations for Which Source is Cited (N=25)		% of Foreign-Controlled Process Innovations for Which Source is Cited (N=57)	
Source	%	Source	%
Suppliers	32	Parent or Affiliate	45
Competitors	16	Suppliers	28
Consultants	16	Written Sources	13
Written Sources	16	Consultants	12

For process innovations, the primary importance of suppliers to Canadian-controlled firms is matched by the importance of foreign parents or affiliates for innovations of foreign-controlled firms.

Consultants and written sources are used for roughly equal proportions of process innovations of both Canadian- and foreign-controlled firms. Competitors rank second in importance as sources of information for innovations by Canadian-controlled firms, but are not important for innovations of foreign-controlled firms.

To eliminate possible variations in use of information sources over firm control due to size differences, we next compare the frequency of use of information sources simultaneously over firm size and control (Tables 7 and 8). For innovations associated with Canadian-controlled firms of all sizes, and for those associated with medium-sized foreign-controlled firms, the most frequently used source of information is customers. Suppliers are utilized by small- and medium-sized Canadian-controlled firms almost twice as often as they are utilized by small- and medium-sized foreign-controlled firms. A foreign parent or affiliate, which is an information source in 41 per cent of all innovations associated with foreign-controlled firms, rises to 52 per cent for innovations

Table 7

PROPORTION OF INNOVATIONS OF CANADIAN-CONTROLLED FIRMS FOR WHICH EACH OUTSIDE INFORMATION SOURCE IS CITED, BY FIRM SIZE

Source	0-100 Employees (N=70)	101-500 Employees (N=33)	More Than 500 Employees (N=12)
		-- (%) --	
Suppliers	17	33	8
Customers	41	48	17
Competitors	11	27	17
Parent or Affiliate	6	3	8
Consultants	7	9	0
Trade Fairs and Associations	4	3	0
Independent Inventors	0	3	0
Government Research Institutes	1	9	0
Universities	1	6	0
Written Sources	9	12	0

Note: Columns do not sum to 100%, since several information sources may be cited for a single innovation.

associated with large foreign-controlled firms. Finally, small and medium-sized Canadian-controlled firms use competitors as an information source much more frequently than do small and medium-sized foreign-controlled firms, which rely more heavily upon parent or affiliated firms.

Table 8

PROPORTION OF INNOVATIONS OF FOREIGN-CONTROLLED FIRMS FOR WHICH EACH OUTSIDE INFORMATION SOURCE IS CITED, BY FIRM SIZE

Source	0-100 Employees (N=45)	101-500 Employees (N=69)	More Than 500 Employees (N=42)
		-- (%) --	
Suppliers	9	16	19
Customers	33	42	19
Competitors	4	16	14
Parent or Affiliate	38	37	52
Consultants	4	9	5
Trade Fairs and Associations	0	0	5
Independent Inventors	2	1	5
Government Research Institutes	0	3	0
Universities	0	4	0
Written Sources	13	8	12

Note: Columns do not sum to 100%, since several information sources may be cited for a single innovation.

Since it was assumed that different information sources might be utilized if the innovation was a result of technology developed in-house as opposed to being based on externally acquired technology, we next examine outside information sources across source of technology and control simultaneously in Table 9. As expected, the parent or affiliate is the information source for 67 per cent of the innovations

Table 9

MOST FREQUENTLY USED OUTSIDE SOURCES OF INFORMATION:
PROPORTION OF INNOVATIONS FOR WHICH INFORMATION SOURCE IS CITED,
BY SOURCE OF TECHNOLOGY AND CONTROL

Source	Innovations Where Technology Developed In-House by Canadian-Controlled Firms (N = 99)	Source	Innovations Where Technology Developed In-House by Foreign-Controlled Firms (N = 88)
Customers	41 %	Customers	39 %
Suppliers	16 %	Parent or Affiliate	20 %
Competitors	15 %	Competitors	17 %
Written Sources	8 %	Written Sources	12 %

Source	Innovations Based on Externally Acquired Technology by Canadian-Controlled Firms (N = 22)	Source	Innovations Based on Externally Acquired Technology by Foreign-Controlled Firms (N = 74)
Suppliers	36 %	Parent or Affiliate	67 %
Customers	27 %	Customers	26 %
Competitors	18 %	Suppliers	19 %
Consultants	18 %	Written Sources	10 %

based on externally acquired technology for foreign-controlled firms. The parent is also an information source in 20 per cent of the foreign-controlled firms' innovations developed via in-house R&D. On the other hand, for innovations of Canadian-controlled firms, customers are of greatest importance in the case of innovations based on technology developed in-house, and rank second after suppliers, for innovations based on technology acquired from a source external to the firm. Customers as an information source are of roughly equal importance to Canadian- and foreign-controlled firms for both sources of technology.

These results parallel the findings reached in Chapter IV in that parent or affiliated firms are the predominant external source of technology for foreign-controlled firms in Canada, whereas suppliers play a similar role for Canadian-controlled firms, though to a much lesser extent. It is apparent, therefore, that parent firms are not only important sources of technology, but are also major sources of ideas for the innovations undertaken by their subsidiaries. Idea generation is an information-intensive activity which is facilitated by corporate relations. Most Canadian-controlled firms do not have the option of relying upon a parent or affiliated firm and so must seek ideas from arm's length sources, a process which is not smoothed via direct links to corporation-wide R&D information and personnel.

When examined at the industry level, results reached regarding the most frequently used sources of information are as expected in light of the foregoing discussion. The two product-oriented industries -- telecommunications equipment and electrical industrial equipment -- most frequently rely upon customers for ideas and information relating to the innovation (Table 10). In contrast, the three remaining industries which, on balance, are process-oriented, rely most heavily upon intracorporate sources for idea generation and information. Suppliers are of some importance as sources of ideas for firms in all of the industries.

Table 10

MOST FREQUENTLY USED OUTSIDE SOURCES OF INFORMATION, BY INDUSTRY

Industry and Source	Number of Innovations for which Source is Cited	% of all Innovations Citing Source
1. Telecommunications Equipment and Components:		
- customers	56	52
- parent or affiliate	26	24
- competitors	18	17
- suppliers	14	13
2. Electrical Industrial Equipment:		
- customers	27	40
- parent or affiliate	18	26
- competitors	9	13
- suppliers	9	13
3. Plastics Compounds and Synthetic Resins:		
- parent or affiliate	13	33
- suppliers	12	30
- customers	10	25
- written sources	7	18
4. Smelting and Refining:		
- parent or affiliate	7	21
- suppliers	7	21
- written sources	5	15
5. Crude Petroleum Production:		
- parent or affiliate	12	40
- suppliers	6	20
- consultants	6	20

Impacts of the Innovations on Firms

The technological change process is defined in this study as consisting of several stages, these being basic and applied research, development, manufacturing start-up and marketing start-up. In earlier chapters, the first three stages have been discussed in detail and thus far in this chapter, we have examined some of the actions which firms must take to initiate the process of technological change, i.e., the decision to innovate and the searching out of information useful in the development of innovations. Just as the process does not begin with invention or innovation but, rather, requires earlier decisions and planning, so does the process not end with manufacturing and marketing start-up; the introduction of new or improved products or processes requires adjustments on the part of the innovating firm. These can most clearly be seen with regard to impacts on workers, both production and non-production, and can be divided into two types: (1) impacts on the number of workers, and (2) impacts on the skill requirements of workers.

In the two sections which follow, the impacts of innovations upon numbers and skills of workers is examined in relation to several characteristics. For example, are there differences between the labour impacts of product and process innovations? Do the labour impacts vary across firm control and size? In the cases in which labour force skill requirements were raised as a result of an innovation's introduction, how were these requirements met for production and non-production workers? Were they primarily hired from outside the firm, retrained in the firm, or sent outside for retraining?

Impacts on Numbers of Workers

Looking at the total number of innovations, it can be seen in Table 11 that the introduction of major innovations throughout the 1960-79 period most often led to increases in the number of workers employed by firms; 62 per cent of the innovations led to increases in the number of production workers and 56 per cent led to increases in the number of non-production workers. Negligible changes in the number of workers was the second most common effect. The firms' introduction of their reported innovations resulted in negligible impacts on the number of non-production workers in 43 per cent of the cases, and resulted in negligible changes in the number of production workers in 31 per cent of the cases. Net decreases in the number of non-production workers rarely resulted from the introduction of the innovations, and for production workers only 7 per cent of the innovations led to net decreases in numbers of employed.

Table 11

PROPORTION OF INNOVATIONS RESULTING IN NET INCREASE, NET DECREASE OR NEGLIGIBLE CHANGE IN THE NUMBER OF PRODUCTION AND NON-PRODUCTION WORKERS, BY INDUSTRY

Industry	Production Workers			Non-Production Workers		
	Negligible	Net Increase	Net Decrease	Negligible	Net Increase	Net Decrease
All Industries	85 (31%)	171 (62%)	17 (7%)	112 (43%)	146 (56%)	2 (1%)
Telecommunications Equipment and Components	24 (22%)	79 (74%)	4 (4%)	36 (35%)	67 (64%)	1 (1%)
Electrical Industrial Equipment	14 (56%)	8 (32%)	3 (12%)	15 (65%)	8 (35%)	0 (0%)
Plastics Compounds and Synthetic Resins	15 (38%)	24 (60%)	1 (2%)	20 (54%)	17 (46%)	0 (0%)
Smelting and Refining	13 (41%)	14 (44%)	5 (15%)	16 (55%)	12 (41%)	1 (4%)
Crude Petroleum Production	18 (27%)	44 (66%)	5 (7%)	23 (37%)	40 (63%)	0 (0%)

At the industry level, similar findings are reached. Net increases in production and non-production workers are predominant, followed by negligible impacts. In only two industries are net decreases in workers worthy of note, and in both cases it was the number of production workers that was affected. In addition, the number of innovations having such effects is extremely small. In the electrical industrial equipment industry, 3 innovations (representing 12 per cent of reported innovations in this industry) are associated with net decreases in the number of production workers while in the smelting and refining industry 5 innovations (15 per cent) have this impact. In neither industry is there any significant decrease in the number of non-production workers as a result of the introduction of innovations.

When we examine the effects on the number of production and non-production workers for product and process innovations separately, a slightly different picture emerges (Table 12). The introduction of product innovations much more frequently led to increases in the number of production and non-production workers, doing so in 70 per cent and 62 per cent of the cases of product innovations, respectively. The introduction of process innovations, in contrast, led to increases in the number of production and non-production workers in only 43 per cent and 41 per cent of the cases of process innovations, respectively. Significantly, the introduction of 20 per cent of all process innovations resulted in a net decrease in the number of production workers. The introduction of neither product nor process innovations had the effect of reducing the number of non-production workers, nor did product innovations cause any net decrease in the number of production workers.

Table 12

PROPORTION OF INNOVATIONS RESULTING IN NET INCREASE, NET DECREASE OR NEGLIGIBLE CHANGE IN THE NUMBER OF PRODUCTION AND NON-PRODUCTION WORKERS, BY TYPE OF INNOVATION

Type of Innovation	Negligible Change No. of Innovations	Negligible Change % of Innovations	Net Increase No. of Innovations	Net Increase % of Innovations	Net Decrease No. of Innovations	Net Decrease % of Innovations
Production Workers:						
product	57	28	139	70	4	2
process	28	37	32	43	15	20
Non-Production Workers:						
product	71	37	117	52	1	1
process	41	58	29	41	1	1

Only small differences exist between Canadian- and foreign-controlled firms in terms of the impact of their innovations on the number of workers (Table 13). The introduction of innovations by Canadian-controlled firms resulted in an increase in the number of both production and non-production workers slightly more often than in the case of foreign-controlled firms, while the innovations of foreign-controlled firms more often show negligible impacts.

Table 13

PROPORTION OF INNOVATIONS RESULTING IN NET INCREASE, NET DECREASE OR NEGLIGIBLE CHANGE IN THE NUMBER OF PRODUCTION AND NON-PRODUCTION WORKERS, BY CONTROL

	Negligible Change		Net Increase		Net Decrease	
Firm Control	No. of Innovations	% of Innovations	No. of Innovations	% of Innovations	No. of Innovations	% of Innovations
Production Workers:						
Canadian-controlled	29	25	79	67	10	8
Foreign-controlled	56	36	92	59	9	5
Non-Production Workers:						
Canadian-controlled	41	37	71	63	0	0
Foreign-controlled	71	48	75	51	2	1

When effects on numbers of production and non-production workers are examined over firm size, it can be seen that the introduction of a greater percentage of the innovations of small firms resulted in net increases in both the number of production and non-production workers (Table 14). Eleven per cent of the innovations of large firms resulted in a net decrease in the number of production workers while only 6 per cent of the innovations of small firms had this effect.

Table 14

PROPORTION OF INNOVATIONS RESULTING IN NET INCREASE, NET DECREASE OR NEGLIGIBLE CHANGE IN THE NUMBER OF PRODUCTION AND NON-PRODUCTION WORKERS, BY FIRM SIZE

	Negligible Change		Net Increase		Net Decrease	
Firm Size	No. of Innovations	% of Innovations	No. of Innovations	% of Innovations	No. of Innovations	% of Innovations
Production Workers:						
0-100 employees	27	25	76	69	7	6
101-500 employees	32	32	65	65	3	3
More than 500 employees	25	47	22	42	6	11
Non-Production Workers:						
0-100 employees	39	37	65	62	1	1
101-500 employees	44	46	52	54	0	0
More than 500 employees	27	52	24	46	1	2

The evidence, in summary, is very consistent. The net effect on firms of introducing innovations is either to increase the number of production and non-production workers or is negligible. There are no significant labour displacement effects, except in the case of some process innovations. Although some of the more recently introduced innovations may not have had time to fully affect employment levels, the results show no cause for overall concern in respect of the labour displacement issue at the level of the innovating firm. Of course, the utilization of some of the product innovations by customer firms may well be significantly affecting numbers of workers employed in user firms in quite different ways. We have no information on the latter important issue.

Impact on Skill Requirements

Respondents were asked in the survey if labour force skill requirements were raised as a result of introducing their innovations. Skill requirements were raised as a result of introducing 71 per cent of all innovations (Table 15). Canadian- and foreign-controlled firms show no difference in the impact of their innovations on skill requirements. There is also no significant difference across firm size. Product innovations tend to result in raised skill requirements only slightly more often than process innovations.

At the industry level, differences in innovations' impacts on skill requirements are more marked (Table 15). Eighty-two per cent of the innovations of firms in the telecommunications equipment and components industry resulted in raised skill requirements, the largest proportion for any single industry. Innovations which least affected skill requirements are those by firms in the plastics compounds and synthetic resins industry where the introduction of 59 per cent of the innovations resulted in raised skill requirements.

Table 15

IMPACT OF INNOVATIONS: PROPORTION RESULTING IN INCREASES IN SKILL REQUIREMENTS, BY TYPE OF INNOVATION, SIZE AND ORIGIN OF CONTROL OF FIRM, AND INDUSTRY

Class	No. of respondents	% where skill requirements were raised
All Innovations	278	71
By Type of Innovation		
Product	198	73
Process	80	67
By Origin of Control of Firm		
Canadian-controlled	120	72
Foreign-Controlled	158	71
By Size of Firm		
0-100 Employees	114	73
101-500 Employees	99	72
More than 500 Employees	53	70
By Industry		
Telecommunications Equipment and Components	106	82
Electrical Industrial Equipment	68	63
Plastics Compounds and Synthetic Resins	39	59
Smelting and Refining	32	72
Crude Petroleum Production	29	66

Three major routes are open to firms in meeting raised skill requirements for both production and non-production workers. They can hire new workers, retrain currently employed workers internally or they can send workers outside for retraining. As can be seen in Table 16, the response is mainly to retrain both types of employee within the firm; for less than 2 per cent of the innovations are production and non-production workers sent outside for retraining. Only 16 per cent

Table 16

HOW SKILL REQUIREMENTS WERE MET FOR PRODUCTION AND NON-PRODUCTION WORKERS, ALL INNOVATIONS

Type of Worker	Hired from Outside		Retrained in Firm		Sent Outside for Retraining	
	No. of Innovations	% of Innovations	No. of Innovations	% of Innovations	No. of Innovations	% of Innovations
Production Workers	25	16	124	82	3	2
Non-Production Workers	45	38	73	61	2	1

of the innovations resulted in new production workers being hired, but 38 per cent resulted in the hiring of new non-production workers. There is no variation in these results across Canadian- and foreign-controlled firms.

With regard to differences in how raised skill requirements are met across firm size, only 11 per cent of the innovations of large firms led to the hiring of production workers from outside the firm, but 20 per cent of the innovations of small firms did so (Table 17). Similarly, 39 per cent of the innovations of small firms led to new non-production workers being hired, while only 24 per cent of the innovations of large firms had this result. On the other hand, large firms more frequently tend to upgrade the skills of their existing labour force through internal retraining programs; production workers were retrained internally as a result of the introduction of 86 per cent of the innovations developed by very large firms and 76 per cent of the innovations of large firms resulted in the internal retraining of non-production workers. In contrast, 79 per cent of the innovations of very small firms led to the internal upgrading of production workers' skills and for only 61 per cent of the innovations were skills of non-production workers upgraded through internal retraining programs.

Table 17

HOW SKILL REQUIREMENTS WERE MET FOR PRODUCTION AND NON-PRODUCTION WORKERS, BY SIZE OF FIRM

	Hired from Outside		Retrained in Firm		Sent Outside for Retraining	
Firm Size	No. of Innovations	% of Innovations	No. of Innovations	% of Innovations	No. of Innovations	% of Innovations
Production Workers:						
0-100 employees	13	20	52	79	1	1
101-500 employees	8	15	45	83	1	2
More than 500 employees	3	11	24	86	1	3
Non-Production Workers:						
0-100 employees	22	39	34	61	0	0
101-500 employees	17	38	26	58	2	4
More than 500 employees	4	24	13	76	0	0

The comparisons set out in Table 17 show that it is new non-production skills which small firms can less easily develop internally. This also reflects their small size in relation to increased work-load associated with the introduction of new manufacturing activities; in large firms, the managerial/administrative infrastructure is more highly developed, and so there is more room to manoeuvre.

The type of innovation introduced also has an effect upon how changes in skill requirements are met, at least with regard to non-production workers (Table 18). For product innovations, a relatively large proportion (41 per cent) resulted in the hiring of new non-production workers, and 58 per cent resulted in existing non-production workers being retrained internally. In the case of process innovations, the internal upgrading of non-production workers' skills through retraining is much more important, being associated with 74 per cent of process innovations; only 22 per cent resulted in the hiring of non-production workers from outside. Little difference between product and process innovations in respect of adjustment to changes in skill requirements for production workers is found. Retraining of production workers within the firm is the predominant means of adjustment for product and process innovations, being used in 80 and 86 per cent of these types of innovations respectively.

Table 18

HOW SKILL REQUIREMENTS WERE MET FOR PRODUCTION AND NON-PRODUCTION WORKERS, BY TYPE OF INNOVATION

Type of Innovations	Hired from Outside		Retrained in Firm		Sent Outside for Retraining	
	No. of Innovations	% of Innovations	No. of Innovations	% of Innovations	No. of Innovations	% of Innovations
Production Workers:						
Product	19	18	86	80	3	3
Process	6	14	38	86	0	0
Non-Production Workers:						
Product	40	41	56	58	1	1
Process	5	22	17	74	1	4

The Patenting of Major Canadian Innovations

Most of the reported innovations introduced over the last 20 years in the five Canadian industries are not patented in Canada.* Only 32 per cent of the reported innovations are patented and there is very little difference in the rate of patenting between product and process innovations. However, the variation in rates of patenting by industry, type of innovation, and over time, show some interesting differences. Table 19 sets out these data.

As expected, patenting rates on new innovations (as opposed to improvement innovations) are relatively high and the same is true for original innovations. Patenting rates on innovations of Canadian-controlled firms are low (23 per cent) as compared to foreign-controlled firms' innovations (39 per cent). Furthermore, innovations by U.S.-controlled firms are even more frequently patented (41 per cent). The low patenting rate for Canadian-controlled innovations is to a limited extent a function of size, as will be seen below.

*The following discussion relates only to whether or not the innovations (product or process) have been patented in Canada.

The source of the technology for the innovation also affects the patenting rate to some extent; 39 per cent of the innovations based on externally acquired technology are patented as compared to only 30 per cent for innovations developed in-house.

When we examine the influence of size on patenting rates, greater variation is in evidence. Patenting rates on the innovations of small and medium-sized firms are quite low relative to larger firms. Only 19 per cent of the innovations of very small firms (50 employees or less) were patented as compared to 48 per cent for firms with over 500 employees. The variation is in the same direction but even more marked when we control for size (total cost) of the innovation directly. For innovations with a total cost of $50,000 or less, only 15 per cent were patented as compared to 54 per cent for innovations with a total cost in excess of $5 million.*

Inter-industry variations are not as marked as we would have expected. In telecommunications equipment, plastics compounds and synthetic resins, and crude petroleum production, almost one-third of the innovations were patented. Innovations in smelting and refining had the highest rate of patenting (55 per cent). The lowest patenting rate is found in electrical industrial equipment. Patenting rates in the electrical products industry in general are known to be quite high, but this subsection (electrical industrial equipment) has very low patenting rates, perhaps reflecting the nature of the products, many of which are highly specialized products for electric power generation and distribution.

We can also examine the propensity to patent over time. There is a very modest tendency for the proportion of major innovations which were patented to decline over time. For innovations introduced in the 1960s, over 40 per cent were patented. However, only 26 per cent

* In addition, patenting rates decline sharply as the pay-back period for the innovation shortens. Forty-three per cent of innovations with a pay-back period of more than 5 years are patented as compared to 29 per cent for innovations with a pay-back period of less than 3 years.

Table 19

RATES OF PATENTING FOR MAJOR CANADIAN INNOVATIONS

Innovation Class	No. of Innovations in Class	Per Cent Patented
All Innovations	274	32
Product	197	32
Process	77	34
New	165	38
Improved	109	25
Original	145	38
Imitation	127	27
Canadian-controlled	116	23
Foreign-controlled	158	39
U.S.-controlled	116	41
Externally acquired technology	74	39
Technology developed in-house	181	30
Firm Size - No. of Employees		
0-50	74	19
51-100	36	33
101-200	45	18
201-500	55	44
more than 500	52	48
Cost of Innovation ($000's)		
0-50	55	15
51-260	72	26
261-1,000	63	38
1,001-5,000	43	44
over 5,000	26	54
Industry		
Telecommunications Equipment and Components	104	32
Electrical Industrial Equipment	67	22
Plastics Compounds & Synthetic Resins	40	33
Smelting and Refining	29	55
Crude Petroleum Production	30	33
Over Time		
Pre-1965	30	40
1965-70	58	45
1971-75	68	31
1976-79	117	26

of the innovations introduced in the last half of the 1970s were patented. The strong tendency for rates of patenting to decline in the 1970s as compared to the 1960s could have a number of explanations. It may simply reflect a tendency on the part of firms to less often patent or it may reflect a tendency for the innovations being produced to be less patentable or less original.*

The following table sets out the behaviour of patenting rates over time by industry. The tendency toward reduced patenting rates in the 1970s is clearly evident at the industry level. In telecommunications equipment, there is an increase in the rate of patenting in the latter half of the 1970s compared to the first half, but even in the latter half of the 1970s the rate is lower than that in the 1960s. The drop in the patenting rate in electrical industrial equipment in the 1970s is most marked of all the industries, but patenting rates in the plastics compounds industry also follows this pattern. There is virtually no change over time in patenting rates in smelting and refining -- they remain high (over 50 per cent patented). In crude petroleum the decline only appears in the last half of the 1970s, but it is a sharp drop. Thus overall, with the exception of smelting and refining, the tendency to reduce rates of patenting over time is fairly pervasive at the industry level. Studies have shown that at least in some industries, there is a tendency for firms to rely less and less on the patent system to protect their major innovations. However, the decline over time is so marked, the possibility that the trends also reflect a change in the quality and size of the major innovations in the 1970s must also be raised;* this is consistent with the findings discussed in Chapter IX regarding changes in the nature and direction of technological change in the 1970s.

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*For some very recently developed innovations, it is possible that not enough time has elapsed for firms to have completed the patenting process, but it is doubtful this consideration is having much effect on the data since firms indicated that a patent was pending in some cases and these were treated as patented innovations.

Table 20

RATES OF PATENTING OVER TIME, BY INDUSTRY

Industry	No. of Innovations in Class	Per Cent of Innovations Patented
Telecommunications Equipment and Components		
Pre-1971	28	54
1971-75	27	27
1976-79	49	49
Electrical Industrial Equipment		
Pre-1971	17	41
1971-75	20	15
1976-79	30	17
Plastic Compounds and Synthetic Resins		
Pre-1971	17	29
1971-75	12	12
1976-79	11	11
Smelting and Refining		
Pre-1971	12	50
1971-75	1	100
1976-79	16	56
Crude Petroleum Production		
Pre-1971	13	38
1971-75	7	42
1976-79	9	22

Finally we can look a little more closely at differences in the propensity to patent between foreign- and Canadian-controlled firms, controlling for size of innovation and for industry variations.

When we control for the size (total cost) of the innovations, the difference between Canadian- and foreign-controlled firms does not in general disappear -- in fact for smaller innovations it becomes more marked (Table 21). Only 5 per cent of the least costly innovations of Canadian-controlled firms are patented as compared to 33 per cent for those of foreign-controlled firms. In general, patenting rates of foreign-controlled firms are higher and less sensitive to the size of the innovation than for Canadian-controlled firms. The higher rate of patenting for the largest Canadian-controlled innovations is

Table 21

RATES OF PATENTING, BY COST OF INNOVATION AND ORIGIN OF CONTROL

Total Cost of Innovation	Canadian-Controlled Firms		Foreign-Controlled Firms	
	No. of Innovations in Class	% of Innovations Patented	No. of Innovations in Class	% of Innovations Patented
($'000)				
0-50	37	5	18	33
51-260	33	21	39	31
261-1,000	23	26	40	45
1,000-5,000	15	40	28	46
Over 5,000	6	83	20	45

worth noting, but there are only 6 cases. In general, foreign-controlled firms have a higher tendency to patent in part because innovations based on imported technology are more often patented in Canada than innovations based on technology developed in-house.

We can also compare rates of patenting between Canadian- and foreign-controlled firms by industry (Table 22). In the telecommunications

Table 22

RATES OF PATENTING, BY INDUSTRY AND ORIGIN OF CONTROL

Industry	Canadian-Controlled		Foreign-Controlled	
	No. of Innovations in Class	% of Innovations Patented	No. of Innovations in Class	% of Innovations Patented
Telecommunications Equipment and Components	56	30	48	33
Electrical Industrial Equipment	28	11	39	31
Plastics Compounds and Synthetic Resins	15	13	25	44
Smelting and Refining	9	33	20	65
Crude Petroleum Production	5	0	25	40

equipment and components industry, patenting rates are similar for the two types of firm. In all of the other industries, however, patenting rates on foreign-controlled innovations are significantly higher than for innovations of Canadian-controlled firms.

Finally, we compare the expenditure profiles of innovations that were patented with innovations which were not patented. There is very little difference. The development spending component is a little higher and the manufacturing start-up component a little lower for innovations which were not patented, but this only reflects the generally larger size of patented innovations in terms of total costs of developing and introducing the innovations. The research and marketing start-up components of the two types of innovations are virtually the same. Thus, the relative importance of R&D in the spending profiles of the innovations does not appear to affect patenting rates.

The Sale or Licensing of Technologies Developed for Major Canadian Innovations

Firms were asked whether or not they licensed or sold any of the technology they developed in the process of producing their major innovations. Since innovation is such an expensive proposition and represents such a burden on the resources of firms, particularly the smaller firms, we wanted to see if there was evidence that the possibility of selling the technology developed in the course of innovating might be serving as a spur to developing innovations in Canada. As we know, international trade in technology has been growing in magnitude over time.

For the 276 innovations on which we received information in this area, 235 represented cases where the technology forming the basis for the innovations was neither sold nor licensed. Thus only 15 per cent of the major innovations developed by firms in Canada led to any sale or licensing of technology. There is virtually no difference between Canadian-controlled and foreign-controlled firms in this respect. There are 41 innovations where the technology was sold or licensed, and we have information on payments received through to the end of 1978 for 32 of these. Average payments received from the sale of these technologies through to the end of 1978 plus average costs of developing these innovations are given in Table 23 for Canadian- and foreign-controlled firms separately.

Table 23

AVERAGE PAYMENTS TO FIRMS FROM THE SALE OF TECHNOLOGIES DEVELOPED FOR MAJOR INNOVATIONS AND AVERAGE TOTAL COSTS OF INNOVATIONS, BY CONTROL

	No. of Innovations	Median Payments Received	Median Total Cost of Innovations
		($000)	($000)
All Innovations with Related Technology Payments	32	150	450
Canadian-Controlled Firms' Innovations	16	75	310
Foreign-Controlled Firms' Innovations	16	175	585

As can be seen in Table 23, although the number of cases is quite small, where technologies were sold they did make a significant contribution to the total costs of developing and introducing the innovations in Canada. The payments to Canadian-controlled firms represent about 24 per cent of the total costs of developing the innovations and these payments amount to close to 30 per cent of total costs for foreign-controlled firms. Since R&D costs alone represent approximately one-half of the total cost of innovations, payments received from the sale or licensing of technology cover over half of the R&D costs of developing the innovations.

Nevertheless, in general, the sale of technologies developed in the course of producing major innovations has not been significant in the five industries. The 41 technology sales that did occur are fairly evenly distributed among the five industries given the relative number of innovations produced in each. When firms were asked about the sale of technology during the follow-up interviews, most said that in the past they had not paid much attention to this issue, but that in future they were considering becoming more active in the sale of technologies abroad. Several firms had recently initiated programs to explore the possibilities and some firms indicated that they had recently had some success in this area. A few large and technologically sophisticated firms said they would not be keen to sell original technology which they had developed in-house because they did not wish to create stronger competitors.

Types of Problems Encountered by Firms Developing and Commercializing Major Innovations

In the survey, firms were asked to indicate the most difficult problem they encountered in developing and commercializing the innovation upon which they were reporting. For the 260 innovations on which information was provided, 10 per cent represent cases where the respondent firm had encountered no significant difficulties in respect of the innovation. Table 24 sets out the most frequently occurring problems, the number of innovations for which the problem was cited, and the percentage of all innovations for which the problem was cited. For the majority of innovations, more than one significant problem was cited.

Table 24

PROBLEMS ASSOCIATED WITH MAJOR INNOVATIONS

Type of Problem	No. of Innovations for Which Problem Cited	% of All Innovations
Technical	98	38
Marketing	55	21
Financial	46	18
Obtaining Necessary Components	26	10
Labour Supply	18	7
Government-Related	16	6

Technical problems refer to the core problems in innovating -- i.e., problems encountered in the development and application of the technology to achieve the desired results. These occurred at the design, development and manufacturing start-up stages with about equal frequency. Marketing problems refer to problems encountered in getting the product onto the relevant market, finding effective distribution outlets, problems with export markets, convincing relevant purchasers to try out the products, selling the product in the hoped-for volumes, etc. The financial problems were considered to be self-evident -- i.e., difficulties in obtaining the necessary funds to develop and launch the innovation. Firms did not supply enough information in this respect to be any more precise (but see Chapters VI and VIII for additional information on the funding of major innovations). Difficulties in obtaining components of the needed type and quality were cited surprisingly often by firms. Labour supply difficulties include difficulties in obtaining skilled manpower of different types in particular and do not refer, for example, to strikes or difficulties in getting workers to co-operate in the introduction of the innovations, which were not cited as problems. Government-related problems include a range of specific problems with government laws, rules, and regulations, from pollution control to tariffs and customs' procedures to procurement policies.

As can be seen in Table 24, the frequency with which each type of problem is cited is not particularly great. For example, although technical problems were by far the most frequently mentioned, they were cited for only 38 per cent of the innovations. Marketing problems were cited for 21 per cent of the innovations, and financial problems for only 18 per cent. The rates of citation for the last 3 problems listed in the table are much lower, but these are very particularized types of problems. When it is also recognized that there is variation in the specific nature of the problems cited within each category, we are led to the conclusion that we cannot put our finger on one or two problems of overriding importance to firms in Canada attempting to develop and introduce major innovations. What is more enlightening is to examine how the frequency of occurrence of the cited problems varies among industries and types of firms.

Table 25 sets out the information separately for product and process innovations and for new vs. improved and original vs. imitative innovations. In general, the variations in the data by type of

Table 25

PROPORTION OF INNOVATIONS FOR WHICH SPECIFIC PROBLEMS IN INNOVATING ARE CITED, BY TYPE OF INNOVATION

Type of Problem	Type of Innovation					
	Product	Process	New	Improved	Original	Imitation
	%					
Technical	36	42	38	38	39	36
Marketing	25	11	23	18	19	25
Financial	19	15	18	18	21	14
Obtaining Necessary Components	11	7	11	8	9	10
Labour Supply	6	8	5	9	6	8
Government-Related	5	10	5	8	5	8

innovation are in the direction one would expect, indicating that the characterizations of the problems encountered are meaningful. For example, technical problems were cited a little more often for process than for product innovations while marketing problems were cited much more often for product innovations; the latter is also true for problems in obtaining necessary components. Government-related problems were cited more for process innovations. When we compare new innovations with improved, both marketing problems and problems in obtaining components become relatively more important for new products and processes than for improvement type innovations, again as would be expected. The variations in the frequency of problems cited is not so great when original and imitative innovations are compared. It should be noted that marketing problems occur more often for imitative innovations and financial problems for original innovations.

The inter-industry variations in the frequency of occurrence of the different types of problems in innovating are set out in Table 26. At the industry level, technical problems still occur most often, but are

Table 26

PROPORTION OF INNOVATIONS FOR WHICH SPECIFIC PROBLEMS IN INNOVATING ARE CITED, BY INDUSTRY

Type of Problem	Telecommunications Equipment and Components (N=103)	Electrical Industrial Equipment (N=65)	Plastics Compounds and Synthetic Resins (N=40)	Smelting and Refining (N=26)	Crude Petroleum Production (N=24)
			-- (%) --		
Technical	35	34	43	38	50
Marketing	22	20	25	19	13
Financial	24	18	8	11	12
Obtaining Necessary Components	14	12	5	0	8
Labour Supply	11	5	5	0	8
Government-Related	4	8	5	8	13
No Problems	6	11	12	19	4

cited relatively more frequently for crude petroleum innovations where technical problems are known to be serious (e.g., in tar sands technology). Marketing problems are relatively most important in the plastics compounds and synthetic resins industry and financial problems are relatively most significant in the two product-oriented industries, particularly telecommunications equipment and components. The same situation applies with respect to problems in obtaining components in that firms in the two product-oriented industries -- electrical industrial equipment and telecommunications equipment -- most frequently mention this problem. Labour supply problems are relatively significant in the telecommunications equipment and components sector and government-related problems are most often cited in respect of crude petroleum production innovations.

We can also compare the problems encountered by Canadian- and foreign-controlled firms in innovating and problems mentioned in respect of innovations with different technology sources. The first comparison in Table 27 relates to differences by origin of control of the firm. Foreign-controlled firms more often experience technical

Table 27

PROPORTION OF INNOVATIONS FOR WHICH SPECIFIC PROBLEMS IN INNOVATING ARE CITED, BY SOURCE OF TECHNOLOGY AND ORIGIN OF CONTROL OF FIRM

	Origin of Control		Source of Technology		
Type of Problem	Canadian (N=116)	Foreign (N=144)	External Technology (N=64)	In-House Technology (N=180)	Combination (N=16)
			-- % --		
Technical	35	40	38	36	63
Marketing	22	21	17	24	6
Financial	30	8	11	20	19
Obtaining Necessary Components	9	10	13	9	6
Labour Supply	7	4	8	7	6
Government-Related	4	8	6	4	25
No Problems	9	10	11	10	0

problems than Canadian-controlled firms (this is to a degree size-related, as will be seen below). It is the Canadian-controlled firms which have difficulties in financing their major innovations (this problem is also size-related to a great degree). Canadian-controlled firms have more problems obtaining workers with the requisite skills, while foreign-controlled firms have more difficulties with government-related problems.

Some of the differences based on source of technology in Table 27 are also interesting. Marketing problems more often occur for innovations based on technologies developed in-house (many of the innovations using imported technologies would have already been marketed abroad), as do financial problems. Problems in obtaining necessary components are more frequently mentioned in the case of innovations based on externally acquired technologies, a reflection of the close technical connection between the technology and the hardware and components. Technical problems are extremely common for innovations employing a combination of externally acquired technology and technology developed in-house, reflecting, perhaps, difficulties in integrating the technologies.

Finally, there is considerable variation in the frequency of occurrence of the different problems in innovating by size of firm. The larger firms much more often experience technical difficulties in developing their innovations than do smaller firms. On the other hand, the very small firms often experience marketing problems (these effects are also product and process related, as seen in Table 25). It is the small firms which experience the greatest problems in financing their major innovations, and the frequency of occurrence of financial problems is very strongly size-related. Thirty-five per cent of the innovations of the very small firms were associated with problems in financing, and this percentage falls steadily with firm size. The very large firms never cited financial problems as a significant problem in developing

Table 28

PROPORTION OF INNOVATIONS FOR WHICH SPECIFIC PROBLEMS IN INNOVATING ARE CITED, BY SIZE OF FIRM

Type of Problem	No. of Employees in Field in 1978				
	0-50 (N=65)	51-100 (N=38)	100-200 (N=45)	201-500 (N=54)	Over 500 (N=47)
Technical	26	32	47	44	45
Marketing	25	21	16	22	21
Financial	35	26	18	7	0
Obtaining Necessary Components	8	16	9	15	6
Labour Supply	5	11	7	6	11
Government-Related	11	3	2	4	4
No Problems	6	8	9	13	11

and introducing their major innovations. The other, more specialized problems do not seem to be size-related, although the frequency of occurrence of problems with government-related laws and regulations is relatively high for the very small firms (less than 50 employees).

Summary

With regard to the decision to innovate, firms of all sizes, both control types and in all industries,indicated that their innovations were motivated by a desire to take advantage of new technological capabilities available within the firm.

Market-related factors were also frequently cited in the decision to innovate. The product innovation-oriented firms and industries, particularly Canadian-controlled and small firms, tended to develop innovations which were directed toward new markets or gaps in existing markets. Large firms, on the other hand, were more oriented toward increasing their existing market shares.

Process-oriented firms and industries, particularly the foreign-controlled and large firms, showed the greatest concern with reducing energy and labour requirements. Quality improvements were also cited as an important motivating factor in the decision to innovate. Some specialized factors influenced the decision to innovate in specific industries.

The sources of ideas and information used by firms in the course of developing their innovations show very strong differences across firm type. Canadian-controlled firms tended to rely upon customers as sources of ideas for their product innovations and upon suppliers and competitors for process innovations.

Foreign-controlled firms, on the other hand, draw upon their parent and affiliated firms to a significant degree for ideas and information relating to their innovations. For product innovations of foreign-controlled firms, the most frequently used source of information was customers, followed by a parent or affiliated firm. In the case of process innovations of foreign-controlled firms, a parent or affiliated firm was the most frequently cited source of information. This use of intracorporate sources of ideas and information among foreign-controlled firms is particularly marked in the cases of innovations based on externally acquired technology.

It is apparent, therefore, that parent and affiliate firms are not only important external sources of technology, as discussed in Chapter IV, but also play a major role in idea-generation and problem-solving for the innovations of their subsidiaries. In most cases, Canadian-controlled firms lack appropriate intracorporate channels and so must deal at arm's-length with less frequently used sources of ideas, information, and technology.

In addition, competitors and suppliers were relatively frequently cited sources of ideas and information for the product innovations of both

Canadian- and foreign-controlled firms, although the importance of suppliers was greater in the case of the Canadian-controlled firms. In respect of process innovations, both types of firm found written sources and consultants to be helpful in the development of their innovations.

In terms of impacts on numbers of workers, net increases in the number of both production and non-production workers are predominant, followed by negligible changes in the numbers employed.

Relative to process innovations, product innovations more frequently led to increases in the numbers of both types of workers employed. Also, small firms more frequently experienced growth in the number of both production and non-production workers than did large firms.

Only in the case of process innovations are net decreases in the number of workers of any note and then only for production workers (20 per cent of the process innovations led to a net decrease in the number of production workers); the introduction of only one process innovation led to a net decrease in the number of non-production workers. Also, the introduction of 11 per cent of the innovations of large firms led to a reduction in the number of production workers; again no significant reduction in the number of non-production workers resulted.

From the results we conclude that, on balance, it is very unlikely the major innovations introduced during the 1960-79 period led to displacement of labour in the innovating firms. In fact, the majority of the innovations resulted in net increases in the numbers of production and non-production workers and a further large proportion had negligible effects on the numbers employed. Of course, the utilization of some of these innovations by customer firms may well be significantly affecting numbers of employed workers in those firms in quite different ways.

The introduction of 71 per cent of the innovations resulted in an increase in labour force skill requirements in the innovating firms. There is no significant variation in this type of impact across firm size and control and, at the industry level, well over half of the innovations in each industry led to increases in skill requirements.

When labour force skill requirements were raised as a result of introducing innovations, firms most frequently tended to retrain their workers internally. This tendency is particularly marked in the case of large firms and process innovations. Small firms had a greater tendency than large firms to hire workers from outside the firm, the difference being largest for non-production workers; 39 per cent of the innovations of small firms led to the hiring of new non-production workers while only 24 per cent of the innovations of large firms did so. Similarly, the hiring of new non-production workers more frequently resulted from the introduction of product rather than process innovations, the figures being 41 and 22 per cent respectively. Very few firms used the option of sending workers outside for retraining if the introduction of the innovation led to increases in skill requirements.

Turning now to the patenting of major innovations, we find that only 32 per cent of the innovations were patented. There is little variation between product and process innovations, although there was a tendency for new and for original innovations to be patented more often than improved and imitative innovations. Forty-eight per cent of the innovations of large firms were patented, but small firms patented only 19 per cent of their innovations. Patenting rates are higher for foreign-controlled firms. Also, there is a strong tendency for patenting rates to decline over time. This is true for the sample as a whole and at the industry level, with the exception of the smelting and refining industry where patenting rates remain relatively high over time.

Only 15 per cent of the major innovations developed by firms in Canada led to any sale or licensing of technology by the innovating firm. There is no difference in this tendency across control. In those cases where technology was sold or licensed, the income received by the innovating firm represents a significant proportion of the total cost of developing the innovation and in fact, would cover about half of the R&D costs of the innovation. In general, however, firms in Canada do not appear to be active in the sale or licensing out of technology.

With regard to problems encountered by firms in innovating, no single problem stands out as the major source of difficulties encountered by firms. The three most frequently cited problems are technical (38 per cent of the innovations), marketing (21 per cent of the innovations), and financial (18 per cent of the innovations). Technical problems were most frequently cited in the case of process innovations, innovations of large firms and foreign-controlled firms, and new (vs. improved) innovations. Difficulties in obtaining components was another type of problem relatively frequently mentioned by firms in producing new (vs. improved) innovations. For product innovations and innovations of small firms, marketing problems were most frequently cited. Canadian-controlled firms and small firms most often experienced financial difficulties in producing their innovations and the larger firms seldom, if ever, cited such problems as a major difficulty.

Chapter VIII

THE FUNDING OF MAJOR CANADIAN INNOVATIONS: WITH PARTICULAR REFERENCE TO EXTERNAL SOURCES OF FUNDS

Introduction

This chapter provides information about the funding of the major innovations in the five industries surveyed. The information pertains particularly to those occasions when firms relied upon external sources to fund all or part of the costs of their innovations. Although the primary focus of the chapter is upon the role of one external source of funds -- government -- we first describe the broader picture by examining all of the main sources of funding of these innovations. In doing so, we begin by delineating those innovations which required at least some external funding from those which did not. We then examine the externally funded innovations in progressively finer detail; first by industry, then by national origin of control of firm (Canadian versus foreign), and finally by firm size.

The data which we have gathered and tabulated are very voluminous, and they have consequently been divided into two sections. One section has been interspersed within the text of this chapter, very much as has been done in the other chapters of this report. The other section, which disaggregates for each of the five industries reviewed on the basis of firm size and control, much of these data, is contained in Appendix A to this chapter. Although the highlights of these appended data are discussed in reasonably self-contained terms in the text, they remain but highlights. It is therefore important that the reader supplement his reading of that part of the chapter with regular references to the tables in the appendix.

Funding of Major Innovations

The delineation of those major innovations which were not funded entirely from the internal resources of the innovating firm from those innovations which were funded in this fashion is begun in Table 1.

Table 1
FUNDING OF MAJOR INNOVATIONS
ALL INDUSTRIES

	No. of Innovations	Per Cent of Total
Innovations Wholly Funded Internally	153	58
Innovations Not Wholly Funded Internally	110	42
Total	263	100

We observe, for example, that of the 263 innovations for which data were provided on sources of funding, 153, or a majority of 58 per cent of the total, were fully funded internally. The majority status of major innovations financed entirely from the internal resources of the innovating firm is preserved, as Table 2 shows, when the innovations are divided between those emerging from Canadian-controlled firms and those from foreign-controlled firms. However, the proportion of innovations wholly funded internally is significantly higher for the foreign-controlled firms. It is also worth noting that 57 per cent of the 263 major innovations for which we have information on funding sources were reported by foreign-controlled firms.

Table 2

FUNDING OF MAJOR INNOVATIONS
BY CONTROL, ALL INDUSTRIES

	Canadian-Controlled Firms		Foreign-Controlled Firms	
	No. of Innovations	% of Total Innovations	No. of Innovations	% of Total Innovations
Innovations Wholly Funded Internally	57	51	96	64
Innovations Not Wholly Funded Internally	56	49	54	36
Total	113	100	150	100

Table 3 disaggregates, on an industry basis, the totals presented in Table 2 relating to major innovations reported as requiring some external funding. This table confirms in a more detailed fashion what Table 2 implied in the aggregate. It shows, in other words, that, in most industries, the majority of reported innovations was funded entirely from the innovating firms' internal resources, that foreign-controlled firms reported more innovations than their Canadian-controlled counterparts, and that these innovations more often were wholly funded internally. However, there are significant inter-industry variations in the proportions of innovations funded wholly internally, particularly in respect of the innovations of the Canadian-controlled firms.

As was discussed in Chapter VI, the size of the firm influences the tendency to fund innovations wholly internally. Small and large firms tend to fund the highest proportion of their innovations wholly internally. It was also found that small and medium-sized foreign-controlled firms tended to fund greater percentages of their innovations wholly internally than was the case for their Canadian-controlled counterparts. For larger firms no

Table 3

FUNDING OF MAJOR INNOVATIONS
BY CONTROL, BY INDUSTRY

	Canadian-Controlled Firms		Foreign-Controlled Firms	
	No. of Innovations	% of Industry Total	No. of Innovations	% of Industry Total
Telecommunications Equipment and Components:				
Innovations Wholly Funded Internally	24	42	24	50
Innovations Not Wholly Funded Internally	33	58	24	50
Total	57	100	48	100
Electrical Industrial Equipment:				
Innovations Wholly Funded Internally	17	63	23	64
Innovations Not Wholly Funded Internally	10	37	13	36
Total	27	100	36	100
Plastics Compounds and Synthetic Resins:				
Innovations Wholly Funded Internally	6	40	18	78
Innovations Not Wholly Funded Internally	9	60	5	22
Total	15	100	23	100
Smelting and Refining:				
Innovations Wholly Funded Internally	9	90	18	78
Innovations Not Wholly Funded Internally	1	10	5	22
Total	10	100	23	100
Crude Petroleum Production:				
Innovations Wholly Funded Internally	1	25	13	65
Innovations Not Wholly Funded Internally	3	75	7	35
Total	4	100	20	100

significant differences were found between the two types of firms (see Table 14 in Chapter VI).

An Overview of the Sources of Funds of Major Innovations Funded Externally in Whole or in Part

Having distinguished the set of major innovations that was reported as having required some funding from one or more sources outside of the innovating firm from the set that was reported as having been fully funded internally, we are now able to proceed with a progressively closer look at the first set, which contains a total of 110 innovations. Beginning again in aggregative fashion, consider Table 4, which presents the amounts contributed by various sources of the total cost of the innovations involved, as well as the percentage that each contribution bears to that total cost.

Table 4

SOURCES OF FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY

Source of Funding	Million $	% of Total
Internal	158.8	18.6
Parent*	219.0	25.8
Private Investors	6.7	0.8
Bond Issue	o	0
Bank:		
conventional loan	89.5	10.5
income debenture and/or floating rate preferred	224.1	26.3
Venture Capital Firm	0.1	0.0
Government	39.5	4.6
Other	114.1	13.4
Total	851.8	100.0

*Denotes, here and throughout, either parent or affiliated firm.

In terms of the aggregate of all 110 major innovations that were wholly or partly funded from external sources, the banks appear as the largest single source, providing 37 per cent of total funding.

Parents (or affiliates) appear as the next most important source, accounting for 26 per cent of total funding. It could be argued, however, that the funds obtained from parents should be added to those generated internally. The grounds for doing so are that this sum represents the total funds obtained from non arm's-length sources -- from what might be termed "the corporate family" -- and is logically distinct from the funds obtained from the other, arm's-length, sources. If this is done, the "corporate family" becomes the largest single source of funds for innovations in this category, having provided 44 per cent of total funding. And government,* which provided a mere 5 per cent of total funding does not appear to loom large as a source of funds.

This aggregated picture of the sources of funding of innovations not wholly funded internally is, however, seriously misleading. This will become increasingly apparent as the above data are disaggregated. For the moment, suffice it to say that the totals attributed to both the banks and parents are heavily dominated by a very few large contributions which, if allowed for, change the picture quite drastically. By the same token, the role of government will emerge as being a good deal more important than is implied in Table 4. Something of this reality is conveyed by Table 5, which gives the total innovations to which each of the sources contributed some funding. This table indicates that the number of innovations supported by parents and by banks were, proportionately, distinctly less than the respective proportions of total funding provided by these sources. Government, conversely, emerges as being a good deal more important than its proportional funding might imply, because over half of these innovations received some government funding.

*"Government" means the federal government in the great majority of cases. Although our data do not enable us to differentiate fully, they do make it clear that only a small proportion of government funding came from provincial sources.

Table 5

SOURCES OF FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY: INNOVATIONS FUNDED TO SOME DEGREE BY VARIOUS SOURCES

	No. of Innovations Receiving Some Funding	Per Cent of Total
Internal	89	81
Parent	26	23
Private Investors	6	5
Bond Issue	0	0
Banks -- Conventional Loan	19	18
-- Debentures/Preferred	2	2
Venture Capital Firm	1	1
Government	62	56
Other	14	12
Total Innovations Not Wholly Funded Internally	110	

Sources of Funding by Industry

Tables 6 and 7 set out, in dollar and percentage terms, respectively, the contributions of the various sources of funding to the total costs of the major innovations reported by each of the industries surveyed that were not wholly funded internally.* They also set out the numbers of such innovations reported by each industry. The overall picture that emerges from these tables is one of contrasts, some of them sharp.

Consider, to begin with, the relationships between total spending in some industries on innovations not wholly funded internally and the associated number of innovations. The smelting and refining industry, for example, reported the fewest innovations in this category (6), but spent much the largest amount on them ($422 million). Similarly, the crude

*For consistency of presentation, the formats of the four tables included in this section will be repeated with appropriately finer detail in the following sections and in Appendix A.

Table 6

CONTRIBUTIONS TO TOTAL FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY
BY SOURCE, BY INDUSTRY

					Bank					
	Internal	Parent	Private Investors	Bond Issue	Conventional Loan	Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
					($ Million)					
Telecommunications Equipment and Components (57)*	18.0	11.5	0.3	0	5.0	0	0.1	9.1	0.4	44.4
Electrical Industrial Equipment (23)	15.4	1.5	0	0	0.3	0	0	7.0	0	24.2
Plastics Compounds and Synthetic Resins (14)	45.6	5.7	0.1	0	4.3	0	0	1.2	0.3	57.2
Smelting and Refining (6)	57.8	10.2	6.3	0	79.9	224.1	0	0.2	43.8	422.3
Crude Petroleum Production (10	22.0	190.1	0	0	0	0	0	22.0	69.6	303.7
Total (110)	158.8	219.0	6.7	0	89.5	224.1	0.1	39.5	114.1	851.8

*Brackets contain number of innovations.

Table 7

PERCENTAGE DISTRIBUTION OF CONTRIBUTIONS TO TOTAL FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY BY SOURCE, BY INDUSTRY

					Bank					
	Internal	Parent	Private Investors	Bond Issue	Conventional Loan	Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
					--(%)--					
Telecommunications Equipment and Components (57)*	40.5	25.8	0.7	0.0	11.3	0.0	0.2	20.5	1.0	100.0
Electrical Industrial Equipment (23)	63.6	6.4	0.0	0.0	1.3	0.0	0.0	28.7	0.0	100.0
Plastics Compounds and Synthetic Resins (14)	79.7	9.9	0.2	0.0	7.6	0.0	0.0	2.1	0.5	100.0
Smelting and Refining (6)	13.7	2.4	1.5	0.0	18.9	53.1	0.0	0.0	10.4	100.0
Crude Petroleum Production (10)	7.3	62.6	0.0	0.0	0.0	0.0	0.0	7.2	22.9	100.0

*Brackets contain number of innovations.

petroleum production industry reported the next lowest number of innovations in this category (10), but spent the second largest amount on them ($304 million). On the other hand, the industry which reported 57 major innovations requiring some outside financing, the largest number in this category -- telecommunications equipment and components -- spent only $44 million on them. It thus ranked fourth in total spending on innovations requiring some external funding.

The contrasts continue as we consider the sources that were relied upon by the various industries for the funding of the major innovations in this category, beginning with those that served the two heaviest spending industries. Both the smelting and refining industry and the crude petroleum production industry generated internally only minor portions of their total funding, and received minor or no funding from government. The former, however, relied heavily upon the banks in funding its innovations (including the rare use of income debentures or term preferred shares); while the latter made no such use of bank funding, instead relying heavily on a non arm's-length source, namely parents.

The other three industries all generated internally large proportions of their total funding of innovations in this category: these ranged from 41 per cent to 80 per cent. The reliance upon parents, on the other hand, was much less than in the preceding cases, ranging from 6 per cent to 26 per cent of total funding. The banks were relatively unimportant. They provided 11 per cent of the total funding of these innovations in the telecommunications equipment and components industry, 8 per cent of the corresponding funding in the plastics compounds and synthetic resins industry, and a mere 1 per cent of that in the electrical industrial equipment industry.

Government, however, was a much more important source of funding for two of these three industries with respect to their innovations requiring external funding. It provided the electrical industrial equipment industry with 29 per cent of its total funding in this area, and the telecommunications equipment and components industry with 21 per cent. It was of negligible importance only to the plastics compounds and synthetic resins industry.

A closer look at the role of government as a source of funds is provided by Tables 8 and 9. Table 8 reveals that 62 innovations, or 56 per cent of the 110 major innovations not wholly funded internally, received some government support. On an industry-by-industry basis, all the industries except smelting and refining received substantial government support in terms of the proportions of total innovations supported, ranging from 48 per cent to 65 per cent of innovations not wholly funded internally. (The smelting and refining industry received government support for only 17 per cent of its innovations which involved external funding.) As to average percentages provided by government of the total funding of the supported innovations, these, too, were considerable. They ranged from 27 per cent to 38 per cent, again except for the smelting and refining industry, in which one innovation received only 8 per cent of its funding from government. When each government contribution is categorized, in Table 9, in terms of the percentage of total cost being funded by government, it turns out that there were more contributions (26) in the 25 per cent - 49 per cent category than in any other. The remaining 36 government contributions were, with two exceptions, evenly divided between the 50 per cent - 74 per cent and the 1 per cent - 24 per cent category.

To summarize, we observe wide variations among the industries surveyed as we consider their reliance upon various sources of funding in financing major innovations not wholly funded internally. We also observe, in three of five industries, that relatively heavy spending on this type of innovation was associated with a relatively low number of innovations reported.

Table 8

AVERAGE PERCENTAGE OF GOVERNMENT CONTRIBUTION TO TOTAL FUNDING*
BY INDUSTRY

	Total Innovations Receiving Some Government Funding	Innovations Receiving Some Government Funding As Per cent of Total Innovations Not Wholly Funded Internally	Average Per cent of Total Funding
Telecommunications Equipment and Components	37	64.9	36.9
Electrical Industrial Equipment	11	47.8	30.1
Plastics Compounds and Synthetic Resins	8	57.1	37.6
Smelting and Refining	1	16.7	8.0
Crude Petroleum Production	5	50.0	27.2
Total	62	56.0	34.5

* of major innovations receiving some government funding.

Table 9

GOVERNMENT CONTRIBUTIONS CATEGORIZED BY PER CENT OF TOTAL FUNDING*
BY INDUSTRY

Industry	75%	50%-74%	25%-49%	1%-24%	Total
		Number of Contributions			
Telecommunications Equipment and Comporents	2	10	17	8	37
Electrical Industrial Equipment	0	3	4	4	11
Plastics Compounds and Synthetic Resins	0	2	5	1	8
Smelting and Refining	0	0	0	1	1
Crude Petroleum Production	0	2	0	3	5
Total	2	17	26	17	62

*of major innovations receiving some government funding.

Sources of Funding, by Control

Control of the innovating firms, Canadian as opposed to foreign, is now introduced (Tables 10 and 11), on an industry-by-industry basis, and again the contrasts are sharp. As indicated elsewhere in this report, the innovations reported by foreign-controlled firms were, on average, much more costly than those reported by Canadian-controlled firms. Consistent with this, it emerges from the data on sources of funding that, in the two industries which spent the most money by far on innovations requiring external funding, practically all of the spending was done by foreign-controlled firms. Indeed, the only industry in which Canadian-controlled firms approximately matched the spending of foreign-controlled firms on this type of innovation was the telecommunications equipment and components industry.

This, however, does not exhaust the contrasts between Canadian-controlled and foreign-controlled firms. Note, for example, that in every case but one, foreign-controlled firms generated internally larger (usually much larger) proportions of the total funding of innovations not wholly funded internally than did their Canadian-controlled counterparts. We also observe that in two of the three industries in which banks were important sources of funding of innovations in this category, foreign-controlled firms relied upon them more heavily than Canadian-controlled firms.

A less varied picture is provided by government behaviour as set out in Tables 12 and 13. Government made contributions to 35 of the 56 innovations made by Canadian-controlled firms that were not wholly funded internally (63 per cent), and to 27 of the 54 such innovations made by foreign-controlled firms (50 per cent). As to the average percentage provided by government of the total funding of those innovations that received some government support, here, too, the contrast between Canadian-controlled and foreign-controlled firms is not great in any industry, except for the

Table 10

CONTRIBUTIONS TO TOTAL FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY BY SOURCE, BY INDUSTRY, BY CONTROL

	Internal	Parent	Private Investors	Bond Issue	Bank: Conventional Loan	Bank: Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
	($ Million)									
Telecommunications Equipment and Components										
- Canadian-Controlled Firms (33)*	8.0	7.9	0.3	0	0.5	0	0.1	4.7	0.4	21.9
- Foreign-Controlled Firms (24)	10.0	3.6	0	0	4.5	0	0	4.4	0	22.5
Electrical Industrial Equipment										
- Canadian-Controlled Firms (10)	1.0	1.0	0	0	0.2	0	0	0.3	0	2.5
- Foreign-Controlled Firms (13)	14.4	0.5	0	0	0.2	0	0	6.7	0	21.7
Plastics Compounds and Synthetic Resins										
- Canadian-Controlled Firms (9)	2.6	0.1	0.1	0	4.3	0	0	0.9	0.1	8.1
- Foreign-Controlled Firms (5)	43.0	5.6	0	0	0	0	0	0.3	0.2	49.1
Smelting and Refining										
- Canadian-Controlled Firms (1)	0.1	0	0	0	0	0	0	0	0.1	0.2
- Foreign-Controlled Firms (5)	57.7	10.2	6.3	0	79.9	224.1	0	0.2	43.7	422.1
Crude Petroleum Production										
- Canadian-Controlled Firms (3)	0	0	0	0	0	0	0	0	2.2	2.2
- Foreign-Controlled Firms (7)	22.2	190.1	0	0	0	0	0	22.0	67.4	301.5
Total Innovations										
- Canadian-Controlled Firms (56)	11.7	9.0	0.4	0	5.0	0	0.1	5.9	2.8	34.9
- Foreign-Controlled Firms (54)	147.1	210.0	6.3	0	84.5	224.1	0	33.6	111.3	816.9
Total (110)	158.8	219.0	6.7	0	89.5	224.1	0.1	39.5	114.1	851.8

*Brackets contain number of innovations.

Table 11

PERCENTAGE DISTRIBUTION OF CONTRIBUTIONS TO TOTAL FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY BY SOURCE, BY INDUSTRY, BY CONTROL

	Internal	Parent	Private Investors	Bond Issue	Bank Conventional Loan	Bank Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
					-- (%) --					
Telecommunications Equipment and Components										
- Canadian-Controlled Firms (33)*	36.4	36.3	1.4	0	2.3	0	0.3	21.5	1.8	100.0
- Foreign-Controlled Firms (24)	44.5	15.7	0		20.1	0	0	19.5	0.2	100.0
Electrical Industrial Equipment										
- Canadian-Controlled Firms (10)	39.0	41.3	0	0	6.8	0	0	12.9	0	100.0
- Foreign-Controlled Firms (13)	66.5	2.3	0	0	0.7	0	0	30.5	0	100.0
Plastics Compounds and Synthetic Resins										
- Canadian-Controlled Firms (9)	32.1	0	1.8	0	53.5	0	0	11.6	1.0	100.0
- Foreign-Controlled Firms (5)	87.5	11.5	0	0	0	0	0	0.6	0.4	100.0
Smelting and Refining										
- Canadian-Controlled Firms (1)	50.0	0	0	0	0	0	0	0	50.0	100.0
- Foreign-Controlled Firms (5)	13.7	2.4	1.5	0	18.9	53.1	0	0.1	10.3	100.0
Crude Petroleum Production										
- Canadian-Controlled Firms (3)	0	0	0	0	0	0	0	0	100.0	100.0
- Foreign-Controlled Firms (7)	7.3	63.0	0	0	0	0	0	7.3	22.4	100.0
Total Innovations										
- Canadian-Controlled Firms (56)	33.6	25.9	1.2	0	14.3	0	0	16.9	8.1	100.0
- Foreign-Controlled Firms (54)	18.1	25.7	0.8	0	10.3	27.4	0	4.1	13.6	100.0
Total (110)	18.6	25.8	0.8	0	10.5	26.3	0	4.6	13.4	100.0

*Brackets contain number of innovations.

Table 12

AVERAGE PERCENTAGE OF GOVERNMENT CONTRIBUTION TO TOTAL FUNDING*
BY INDUSTRY, BY CONTROL

	Canadian-controlled firms			Foreign-controlled firms		
	Innovations Receiving Some Government Funding	Innovations Receiving Some Government Funding as Per cent of Total Innovations Not Wholly Financed Internally	Average Per cent of Total Funding	Innovations Receiving Some Government Funding	Innovations Receiving Some Government Funding as Per cent of Total Innovations Not Wholly Financed Internally	Average Per cent of Total Funding
Telecommunications Equipment and Components	23	69.7	38.5	14	58.3	34.2
Electrical Industrial Equipment	4	40.0	27.5	7	53.9	31.6
Plastics Compounds and Synthetic Resins	6	66.7	36.0	2	40.0	42.5
Smelting and Refining	0	0	0	1	20.0	8.0
Crude Petroleum Production	2	66.7	10.0	3	42.9	38.7
Total	35	62.5	35.2	27	50.0	33.7

* of major innovations receiving some government funding.

Table 13

GOVERNMENT CONTRIBUTIONS CATEGORIZED BY PER CENT OF TOTAL FUNDING*
BY INDUSTRY, BY CONTROL

	Canadian-controlled firms					Foreign-controlled firms				
	75%+	50%-74%	25%-49%	1%-24%	Total	75%+	50%-74%	25%-49%	1%-49%	Total
	Number of Contributions									
Telecommunications Equipment and Components	2	7	11	3	23	0	3	6	5	14
Electrical Industrial Equipment	0	1	1	2	4	0	2	3	2	7
Plastics Compounds and Synthetic Resins	0	2	3	1	6	0	0	2	0	2
Smelting and Refining	0	0	0	0	0	0	0	0	1	1
Crude Petroleum Production	0	0	0	2	2	0	2	0	1	3
Total	2	10	15	8	35	0	7	11	9	27

* of major innovations receiving some government funding.

crude petroleum production industry, where the former received an average government contribution of 10 per cent and the latter of 39 per cent of the total cost of supported innovations. Much the same can also be said when government contributions are categorized on the basis of the percentages which they represent of total cost of the innovations supported. In total, the largest government-funding category of both types of control is the 25 per cent - 49 per cent category, and the remaining contributions are more or less evenly divided between the next highest and the next lowest categories. Inevitably, however, this needs some qualification when we look at the industry breakdown In the crude petroleum production industry, for example, both of the two contributions by government to Canadian-controlled firms were in the 1 per cent - 24 per cent category, while foreign-controlled firms received two of their three contributions in the 50 per cent - 74 per cent category: the remaining one was in the 1 per cent - 24 per cent category. On the other hand, in the telecommunications equipment and components industry, the Canadian-controlled firms received more large-category government contributions than did the foreign-controlled firms.

We may say, therefore, in summarizing this section, that, as was foreshadowed earlier, spending on innovations requiring external funding was dominated in every industry save one by foreign-controlled firms. Government, however, was fairly even handed in allocating its support of the innovations reported by these industries.

Sources of Funding, by Firm Size

The firm size dimension is now introduced on an industry-by-industry basis, by itself in this section -- set out in Tables 14 and 15* -- and in conjunction with Canadian or foreign control in the next few sections.

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*We have not in this section drawn up tables setting out government contributions similar to those pertaining to the preceding two sections. In the interests of clarity, tables along these lines have been prepared separately for each industry. They, together with the other industry-specific tables reviewed in the following sections, are contained in Appendix A.

Table 14

CONTRIBUTIONS TO TOTAL FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY
BY SOURCE, BY INDUSTRY, BY SIZE

		Internal	Parent	Private Investors	Bond Issue	Bank: Conventional Loan	Bank: Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
		($ Million)									
Telecommunications Equipment and Components											
100 or less employees	(34)*	5.9	1.7	0.3	0	4.7	0	0.1	3.7	0.4	16.8
101-500 employees	(18)	4.8	9.8	0	0	0.3	0	0	2.7	0	17.6
over 500 employees	(5)	7.3	0	0	0	0	0	0	2.7	0	10.0
Total	(57)	18.0	11.5	0.3	0	5.0	0	0.1	9.1	0.4	44.4
Electrical Industrial Equipment											
100 or less employees	(10)	0.7	0.5	0	0	0.2	0	0	0.2	0	1.6
101-500 employees	(11)	2.2	1.0	0	0	0.1	0	0	1.0	0	4.3
over 500 employees	(2)	12.5	0	0	0	0	0	0	5.8	0	18.3
Total	(23)	15.4	1.5	0	0	0.3	0	0	7.0	0	24.2
Plastics Compounds and Synthetic Resins											
100 or less employees	(4)	0.4	0	0	0	0	0	0	0.3	0	0.7
101-500 employees	(9)	4.0	5.7	0.1	0	4.3	0	0	0.9	0.3	15.3
over 500 employees	(1)	41.2	0	0	0	0	0	0	0	0	41.2
Total	(14)	45.6	5.7	0.1	0	4.3	0	0	1.2	0.3	57.2
Smelting and Refining											
100 or less employees	(3)	0.1	2.6	0	0	5.2	0	0	0.2	0.1	8.2
101-500 employees	(1)	12.7	0	6.3	0	0	0	0	0	6.3	25.3
over 500 employees	(2)	45.0	7.6	0	0	74.7	224.1	0	0	37.4	388.8
Total	(6)	57.8	10.2	6.3	0	79.9	224.1	0	0.2	43.8	422.3
Crude Petroleum Production											
100 or less employees	(4)	2.5	0	0	0	0	0	0	6.2	5.9	14.6
101-500 employees	(3)	17.7	189.8	0	0	0	0	0	15.8	63.2	286.5
over 500 employees	(3)	1.8	0.3	0	0	0	0	0	0	0.5	2.6
Total	(10)	22.0	190.1	0	0	0	0	0	22.0	69.6	303.7
Total	(110)	158.8	219.0	6.7	0	89.5	224.1	0.1	39.5	114.1	851.8

*Brackets contain number of innovations.

Table 15

PERCENTAGE DISTRIBUTION OF CONTRIBUTIONS TO TOTAL FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY BY SOURCE, BY INDUSTRY, BY SIZE

						Bank					
		Internal	Parent	Private Investors	Bond Issue	Conventional Loan	Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
						-- (%) --					
Telecommunications Equipment and Components											
100 or less employees	(34)*	35.2	9.8	1.8	0	28.1	0	0.4	22.1	2.6	100.0
101-500 employees	(18)	27.3	55.7	0	0	1.8	0	0	15.2	0	100.0
over 500 employees	(5)	72.9	0	0	0	0	0	0	27.1	0	100.0
Electrical Industrial Equipment											
100 or less employees	(10)	44.1	31.9	0	0	14.3	0	0	9.7	0	100.0
101-500 employees	(11)	51.2	24.0	0	0	2.3	0	0	22.5	0	100.0
over 500 employees	(2)	68.3	0	0	0	0	0	0	31.7	0	100.0
Plastics Compounds and Synthetic Resins											
100 or less employees	(4)	53.0	0	0	0	5.3	0	0	41.7	0	100.0
101-500 employees	(9)	26.2	36.7	0.1	0	28.0	0	0	6.2	1.9	100.0
over 500 employees	(1)	100.0	0	0	0	0	0	0	0	0	100.0
Smelting and Refining											
100 or less employees	(3)	1.2	31.5	0	0	63.4	0	0	2.7	1.2	100.0
101-500 employees	(1)	50.0	0	25.0	0	0	0	0	0	25.0	100.0
over 500 employees	(2)	11.6	2.0	0	0	19.2	57.6	0	0	9.6	100.0
Crude Petroleum Production											
100 or less employees	(4)	17.3	0	0	0	0	0	0	42.6	40.1	100.0
101-500 employees	(3)	6.2	66.2	0	0	0	0	0	5.5	22.1	100.0
over 500 employees	(3)	67.5	13.6	0	0	0	0	0	0	18.9	100.0

*Brackets contain number of innovations.

We start with large firms (over 500 employees). These firms relied heavily in all industries, except smelting and refining, upon their own internal resources, even when they went outside for some funding for their major innovations. They made, however, little use of the banks as a source of innovation funding. On the other hand, large firms in two industries -- telecommunications equipment and components and electrical industrial equipment -- received significant proportions of the funding of these innovations from government. Large firms in the other three industries received little or no government funding.*

Medium-sized firms (101-500 employees) in all industries, except, again, those in smelting and refining, made substantial use of parent firms as a source of major innovation funding. This is the only size group that did so. In addition, medium-sized firms in all industries, except those in the crude petroleum production industry, generated internally substantial proportions of the total costs of innovations requiring external funding. The banks, once again, played no significant role in relation to medium-sized firms, except for those in plastics compounds and synthetic resins. As to reliance upon government support, the only medium-sized firms to do so to a significant extent were those in telecommunications equipment and components and in electrical industrial equipment.

The picture for small firms (less than 100 employees) is quite different. Banks, for example, were a substantial source of innovation funding in three industries: telecommunications equipment and components, electrical industrial equipment, and smelting and refining. On the other hand, small firms tended in most industries to obtain a lesser proportion of major innovation funding from their respective parents than did larger firms. Differences also appeared with respect to the role of government as a source of innovation funding. In two industries, plastics compounds and synthetic resins and crude petroleum production,

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*As will emerge when we consider some specific government programs, there were a few government contributions which were too small to show up in most of the tables. They do appear, however, in the tables specifically concerned with the program involved.

government provided small firms with over 40 per cent of their total funding of innovations in this category. Small firms in the telecommunications equipment and components industry also received a significant 22 per cent of total funding of innovations in this category. Indeed, only small smelting and refining firms received negligible government support.

A major implication of this section is that large and medium-sized firms tended to generate internally or obtain from parents larger proportions of the costs of major innovations requiring external funding than did small firms. Another is that government played, on the whole, a more important role in funding innovations of small and large firms than it did those of medium-sized firms.

Sources of Funding, by Firm Size and Control, by Industry

Introduction

A much richer verisimilitude of analysis than was attainable from the data described heretofore now becomes available as we look at data pertaining simultaneously to the firm size and control dimensions. This is done below, with each industry considered separately. In the interests of consistency of presentation a set of four tables has been prepared for each industry which is analogous to the preceeding tables for all of the industries together. Because of their number, these twenty tables could not be interspersed conveniently within the text: they have therefore been collected sequentially in Appendix A to this chapter. In order to better follow the review of these data that is presented below, the reader is again urged to refer regularly to the tables in the appendix.

Telecommunications Equipment and Components*

This industry made, as was mentioned above, the largest number (57) of major innovations requiring some degree of external funding, although it ranked quite low in terms of total spending on such innovations ($44 million). Approximately 60 per cent of these innovations emerged from Canadian-controlled firms and approximately 40 per cent from foreign-controlled firms. Total spending on these innovations, however, was evenly divided between the two control groups.

Differences between the two control groups in this industry become rather more pronounced as we consider firm size. Large foreign-controlled firms spent some $8 million on innovations not wholly funded internally -- over three times as much as was spent by large Canadian-controlled firms on such innovations -- although the numbers of innovations reported were not far apart: 3 and 2. On the other hand, medium-sized Canadian-controlled firms spent almost $13 million on innovations requiring some external funding compared with $5 million spent by their foreign-controlled counterparts. This disparity in total spending between these two control groups did not, however, reflect their reported numbers of innovations in this category: the Canadian-controlled firms reported 8 innovations while the foreign-controlled firms reported 10. Contrasts also emerge from the relative performances of small firms. Although the total spending by the two small-sized control groups on innovations not wholly funded internally did not differ greatly (Canadian-controlled firms spent $7 million and foreign-controlled firms $10 million), the total innovations reported did. Canadian-controlled firms reported 23 innovations in this category while foreign-controlled firms reported only 11.

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*See Tables A-1 through A-4 in Appendix A.

As to sources of funding, the firms and their parents generated between them half or more of the total funds required for these innovations in all of the size/control groups in this industry save one. The single exception, small foreign-controlled firms, generated only 30 per cent of the funding of these innovations from this source. On the other hand, it obtained almost half from banks: indeed, this was the only size/control group in the industry to make more than negligible use of banks for funding innovations.

Government contributed significantly to the total funding of the innovations not wholly funded internally that were made by all six size/control groups in this industry. These contributions ranged from 10 per cent of total spending by medium-sized foreign-controlled firms to 50 per cent of total spending by large Canadian-controlled firms. In most cases, however, the percentage of total spending provided by government was around 20 per cent.

A much more precise picture of government's role emerges when we focus specifically on the innovations made by this industry which received some government support. These innovations, to begin with, represented almost 70 per cent of all innovations not wholly funded internally made by Canadian-controlled firms and 60 per cent of those made by foreign-controlled firms. At least half (usually more) of the innovations in this category by every size/control group received some government support. Also, the percentage of the total funding of these innovations that was provided by government was always significant, and in many cases it was very significant indeed. For example, almost half of the government-supported innovations reported by Canadian-controlled firms received from 25 per cent to 49 per cent of total funding from government, and almost one-third received from 50 per cent to 74 per cent of total funding. Similar proportions of corresponding innovations made by foreign-controlled firms were also funded to these same degrees by government.

This, then, is an industry in which innovations requiring external funding were numerous in comparison with the other four industries surveyed, but it is also an industry in which such innovations cost, on average, less than they did in most of the other industries. A clear majority of these innovations were reported by Canadian-controlled firms, although the total amounts spent upon them did not differ greatly between Canadian-controlled and foreign-controlled firms. Large foreign-controlled firms spent around twice as much, per innovation requiring external funding, than their Canadian-controlled counterparts: the corresponding ratio between small foreign-controlled firms and small Canadian-controlled firms was even higher.

Government played an important role in the funding of externally funded innovations reported by this industry, a role which, though unevenly distributed among the six size-control groups, was significant to all of them.

Electrical Industrial Equipment*

When the total spending on innovations that required some outside funding that was done by each of the size/control groups in this industry is considered, that done by large foreign-controlled firms stands out dramatically. Of the $24 million spent on such innovations by the five groups involved, $18 million was spent by this one group alone, a performance that is all the more striking when it is noted that only 2 innovations (out of an industry total of 23 in this category) were involved. One of these two innovations cost $15 million, the other $3 million.

If we abstract from this distinctive element, the picture becomes considerably less varied. Total innovations reported in this industry in this category were, for example, almost evenly divided

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* See Tables A-5 through A-8 in Appendix A.

between Canadian-controlled and foreign-controlled firms. Also, every size/control group generated at least two-thirds of its total funding either internally or in conjunction with a parent firm. Similarly, government was a significant (if uneven) contributor to each of the five size/control groups in the industry that reported innovations partly funded externally.

Looking more closely at the role of government, we note, to begin with, that 11 of the 23 innovations reported by this industry in this category received some government support: 4 of these were reported by Canadian-controlled firms and 7 by foreign-controlled firms. In the former group, 2 of these innovations apiece were reported by small and medium-sized firms. In the latter group, one government-supported innovation was reported by a small firm, 4 by medium-sized firms, and 2 by large firms. As to the percentage-of-total-cost category into which government contributions fell, of the 4 government-supported innovations reported by Canadian-controlled firms, 2 were in the 1 per cent - 24 per cent category and there was one each in the 25 per cent - 49 per cent and the 50 per cent - 74 per cent categories. The corresponding distribution for foreign-controlled firms was 4, 4 and 3, respectively. There was no real clustering of these government contributions in any of the size/control groups.

On the whole, this industry -- once we adjust for the two unusually costly members of the set of innovations not wholly funded internally -- is characterized by relatively few striking differences between Canadian-controlled and foreign-controlled firms. There was also a quite strong tendency for firms to fund these innovations with internal funds or with funds obtained from a non arm's-length source. Almost half of these innovations received some government support, much of it considerable. Although more such innovations reported by foreign-controlled firms received government support than were reported by Canadian-controlled firms, it cannot otherwise be said that government support was concentrated in any size/control group.

Plastics Compounds and Synthetic Resins*

This industry is analogous to some of the other industries under review, in that a single innovation that required some external funding reported in a single size/control group dominates (and distorts) the overall picture. A large foreign-controlled firm spent $41 million on one such innovation, whereas the industry as a whole spent $57 million on 14 innovations. If we allow for this unusually large expenditure, the contrasts in the rest of this industry become, as before, much less striking, though some are still noteworthy.

The firm and /or its parent were the overwhelmingly important sources of funds for the five major innovations not wholly funded internally reported by foreign-controlled firms. Four of these innovations were reported by medium-sized firms (the other, enormously costly one has already been mentioned), and the total amount spent on them was $8 million. Almost the same total was spent on nine corresponding innovations by Canadian-controlled firms. In this group, however, almost the whole of this total, over $7 million, was spent by medium-sized firms on five innovations, while small firms spread a mere $0.7 million over the remaining four innovations. Another difference between the two control groups in this industry is the fact that only in the case of small firms did Canadian-controlled firms generate within the "corporate family" over half of total spending on this category of innovations. Yet another difference lies in the fact that medium-sized Canadian-controlled firms constitute the only size/control group in this industry that relied significantly upon banks as a source of funds -- to the extent of 58 per cent of the total funding of innovations not wholly funded internally.

Of the 14 major innovations reported by this industry which required some external funding, eight received some government support. Six of these emerged from Canadian-controlled firms, two-thirds of that

*See Tables A-9 through A-12 in Appendix A.

control group's total innovations in this category. Two of the five such innovations reported by foreign-controlled firms (40 per cent) also received some government support. On average, the proportion of the total funding of these innovations that was provided by government ranged from 32 per cent to 43 per cent. Five of the 8 government-supported innovations were reported by medium-sized firms (3 Canadian-controlled and 2 foreign-controlled): the remaining 3 were made by small Canadian-controlled firms. Three of the 6 government-supported innovations reported by Canadian-controlled firms received between 25 per cent and 49 per cent of their total cost from government. Foreign-controlled firms reported that 5 of their 8 government-supported innovations were in this percentage range.

It may therefore be said, on balance, that this industry is distinguished mainly in two respects. Perhaps the more important of these is the reliance of medium-sized Canadian-controlled firms upon the banks for over half of their total funding of major innovations requiring some external funding. The other is the strong support given by government to the innovations in this category reported by small Canadian-controlled firms.

Smelting and Refining*

We have in this industry another situation in which the overall picture is dominated and therefore distorted by disproportionate elements. As was noted earlier, total spending by smelting and refining firms on major innovations requiring some external funding amounted to $422 million, far more than was spent on corresponding innovations by any of the other industries under review. On the other hand, a total of only 6 innovations was produced by this volume of spending, the lowest of the five industry totals. Of these 6 innovations not wholly funded internally, the 2 innovations reported by large foreign-controlled firms accounted for over 90 per cent of the total spending by the industry on such

*See Tables A-13 through A-16 in Appendix A.

innovations: $389 million out of $422 million. As was the case in the analogous (in this respect) electrical equipment industry, these 2 innovations involved radically different total costs: one involved $374 million, the other $15 million.

This industry is also distinctive in the sources from which the funding was obtained for its major innovations not wholly funded internally. The firm or its "corporate family" were generally rather less important sources of funds than they were in the other industries. For example, only 2 of the 4 size/control groups reporting innovations in this category -- small Canadian-controlled firms and medium-sized foreign-controlled firms -- generated as much as half of the necessary funds internally (there was nothing from parents, if any). Interestingly, small foreign-controlled firms applied no internal funds to their 2 innovations, but obtained 32 per cent of the total costs from parents and 65 per cent from banks.* It is also worth mentioning that the miscellany of sources categorized in the survey as "other"** was relatively important in this industry. They provided half of the funds required for its single innovation in this category by a small Canadian-controlled firm, as well as 25 per cent of the corresponding requirement of a medium-sized foreign firm. An additional feature of this industry, unique in the survey, is the single instance of the use on a large scale of income debentures or term preferred shares in borrowing from banks to fund an innovation. The above-mentioned innovation that cost $374 million was funded to the extent of $224 million by means of one of these instruments.

Government was a much less important source of funding of innovations in this industry than it was in the others surveyed. Only one innovation, reported by a small foreign-controlled firm, was supported

*Being aggregative, however, this statement is somewhat misleading. One of these 2 innovations, costing $2.8 million, was funded to the extent of 92 per cent by the parent firm. The other innovation, which cost $5.2 million was financed entirely by bank credit. But the primary point, that no internal funds were applied to these innovations remains unaltered.

**Which includes customers, suppliers, research institutes, and co-operating firms.

by government; in this case to the extent of 8 per cent of the total cost of the innovation.

Crude Petroleum Production*

This is yet another industry in which total spending on major innovations requiring some external funding is concentrated disproportionately in a single size/control group. Of an industry total of $304 million, representing 10 innovations, $287 million was spent in the medium-sized foreign-controlled group on 3 innovations. Here, too, one innovation dominated the picture. Its total cost was $253 million, of which $190 million came from the parent of the innovative firm (while the firm itself, surprisingly, contributed no internal funds). The remaining $63 million spent on this innovation came from "other" sources.

Looking at the rest of this industry's sources-of-funds picture, there are some other notable features. One of these is the absence of reliance upon the banks as a source of funding of innovations. Another is the relatively more important role of "other" sources of funds. And a third is the fact that small firms in this industry generated very little of their funding of innovations not wholly funded internally either within the firm or within the "corporate family". Indeed, small Canadian-controlled firms -- the only Canadian-controlled firms reporting innovations in this category -- generated no funds internally or from parents, if any. Virtually all of the funds for their 3 innovations in this category came from "other" sources. Government's contributions were small.**

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*See Tables A-17 through A-20 in Appendix A.

**Too small to warrant inclusion in Tables A-17 and A-18, which are expressed to the nearest $100,000. They are, however, listed in Tables A-19 and A-20.

Government contributed more heavily to innovations by foreign-controlled firms. Three of the seven innovations requiring some outside funding that were reported by this group received some government funds. These funds went to small and medium-sized firms. The government contribution to a small foreign-controlled firm represented 50 per cent of the total cost of the innovation involved. The 2 government contributions that went to medium-sized foreign-controlled firms varied in relative magnitude. Expressed as a percentage of the total costs of the supported innovations involved, one fell in the 50 per cent - 74 per cent category and the other in the 1 per cent - 24 per cent category.

Apart from a rather unusual reliance upon miscellaneous "other" sources of funding for the financing of major innovations not wholly funded internally, this industry is on the whole characterized by two features. One of these is an absence of reliance upon banks for the funding of innovations; the other is the relatively unimportant role played by government as a source of innovation funding.

Four Federal Programs

A significant number of respondents was able to provide information about specific federal government programs. This information, outlined below, refers to four programs. These programs are: the Program for the Advancement of Industrial Technology (PAIT), the Defence Industry Productivity Program (DIPP), the Industrial Research Assistance Program (IRAP), and the Industrial Research and Development Incentives Act (IRDIA).

A total of 17 PAIT contributions were reported, as shown in Table 16.* Twelve of these went to firms in the telecommunications equipment and components industry. Although a majority (seven) of these went to small and medium-sized Canadian-controlled firms, the total dollars involved were only about one-third of the total amount contributed to

*Seven innovations were reported as having received some funding from more than one government program, but the contributions received from each program were not indicated. These innovations have been disregarded for the purposes of this section.

Table 16

PAIT CONTRIBUTIONS

		Total Contributions	Total Funding	Average Percent Contribution to Total Funding*
		$ Million		
Telecommunications Equipment and Components				
Canadian-controlled firms				
100 or less employees	(4)**	0.4	1.3	38.8
101-500 employees	(3)	0.3	1.0	30.0
Total	(7)	0.7	2.3	
Foreign-controlled firms				
100 or less employees	(2)	0.9	4.1	34.5
101-500 employees	(1)	0.2	0.4	40.0
over 500 employees	(2)	1.1	2.8	40.0
Total	(5)	2.2	7.3	
Electrical Industrial Equipment				
Canadian-controlled firms				
100 or less employees	(1)	0.07	0.20	35.0
101-500 employees	(1)	0.16	0.32	50.0
Total	(2)	0.23	0.52	
Foreign-controlled firms				
101-500 employees	(1)	0.18	0.60	30.0
over 500 employees	(1)	5.50	15.30	36.0
Total	(2)	5.68	15.90	
Crude Petroleum Production				
Foreign-controlled firms				
101-500 employees	(1)	0.4	2.8	16.0

*of major innovations receiving some PAIT funding.
**Brackets contain number of innovations.

foreign-controlled firms in this industry. This was not primarily due to different proportions being provided of the total costs of the innovations supported by this program -- these, on the whole, did not vary greatly. Rather, it was due to the fact that the supported innovations reported by foreign-controlled firms, mostly in the small- and large-sized groups, involved about three times as much money as those reported by comparably sized Canadian-controlled firms.

Four PAIT contributions went to firms in the electrical industrial equipment industry, two to Canadian-controlled firms and two to foreign-controlled firms. Even more than was the case in the telecommunications equipment and components industry, much more progam money went to foreign-controlled firms. The reason, however, was the same: the supported innovations reported by foreign-controlled firms involved much greater sums of money. The remaining PAIT contribution went to a medium-sized foreign-controlled firm in the crude petroleum industry. Expressed as a percentage of the total cost of the supported innovations, however, it was the smallest of the 17 contributions reported, being only 16 per cent.

Only one DIPP contribution, set out in Table 17, was reported. It went to a large Canadian-controlled firm in the telecommunications equipment and components industry and it represented 50 per cent of the total cost of the supported innovation.

Table 17

DIPP Contributions

		Total Contributions	Total Funding	Average Percent Contribution to Total Funding*
		($ Million)		
Telecommunications Equipment and Components				
Canadian-Controlled Firms				
over 500 employees	(1)**	0.47	0.93	50.0

*of major innovations receiving some DIPP funding.
**Brackets contain number of innovations.

Fifteen IRAP contributions were reported and are set out in Table 18. Seven of these went to small Canadian-controlled firms in the telecommunications equipment and components industry. Six went to the plastics compounds and synthetic resins industry -- three to small Canadian-controlled firms and one to a large one. Two went to medium-sized foreign-controlled firms. The remaining two contributions went respectively to a medium-sized and a large-sized foreign-controlled firm in the crude petroleum production industry. In keeping with the purpose of IRAP, to help defray the costs of hiring scientific personnel, most of the contributions were in relatively small amounts, and averaged over 40 per cent of total costs.

Seven IRDIA contributions were reported, and these are set out in Table 19. Four went to the telecommunications equipment and components industry, evenly divided between Canadian-controlled and foreign-controlled firms. Three went to small firms and one to a medium-sized firm. The electrical industrial equipment industry received one contribution, to a small Canadian-controlled firm. The remaining two contributions were made to small Canadian-controlled firms in the crude petroleum production industry. Most of the IRDIA contributions represented small proportions of the total costs of the innovations supported.

Summary

It was clearly implied above that reviewing the outside funding of the innovative behaviour of the reporting firms in the industries surveyed is something of a study in contrasts. These contrasts reflect, above all, the very different characteristics of both the firms and their respective industries. They reflect, in other words, the very different distributions of such important factors as firm size, firm control and market shares, etc., that obtain in these industries. They are also a reflection of the fact that the respective rates of technological change in the industries, and their general technological environments,

Table 18

IRAP CONTRIBUTIONS

		Total Contributions	Total Funding	Average Percent Contribution to Total Funding*
		$ Million		
Telecommunications Equipment and Components				
Canadian-controlled firms				
100 or less employees	(7)**	0.5	1.0	50.0
Plastic Compounds and Synthetic Resins				
Canadian-controlled firms				
100 or less employees	(3)	0.270	0.620	43.5
101-500 employees	(1)	0.002	0.004	50.0
Total	(4)	0.272	0.624	
Foreign-controlled firms				
101-500 employees	(2)	0.28	0.67	41.8
Crude Petroleum Production				
Foreign-controlled firms				
101-500 employees	(1)	0.1	0.4	25.0
over 500 employees	(1)	0.3	3.0	10.0
Total	(2)	0.4	3.4	

*of major innovations receiving some IRAP funding.
**Brackets contain number of innovations.

Table 19

IRDIA CONTRIBUTIONS

		Total Contributions	Total Funding	Average Percent Contribution to Total Funding*
		$ Million		
Telecommunications Equipment and Components				
Canadian-controlled firms				
100 or less employees	(1)**	0.04	0.08	50.0
101-500 employees	(1)	0.04	1.80	2.0
Total	(2)	0.08	1.88	
Foreign-controlled firms				
100 or less employees	(2)	0.56	5.31	10.0
Electrical Industrial Equipment				
Foreign-controlled firms				
100 or less employees	(1)	0.07	0.33	20.0
Crude Petroleum Production				
Canadian-controlled firms				
100 or less employees	(2)	0.006	0.06	10.0

* of major innovations receiving some IRDIA funding.

** Brackets contain number of innovations.

inevitably varied very considerably over the period surveyed (as they have probably varied in the past). Add to these considerations both the small-sample problems and the disproportionately costly innovations that have been noted, and it becomes abundantly clear that any temptation to offer sweeping generalizations on the basis of the data presented in this chapter should be firmly resisted.

This, however, is not intended to imply that only intra-industry generalizations are warranted: there are, in fact, a number of observable features in the data which transcend specific industries. One of these features is, of course, the important contributions made by foreign-controlled firms, in terms of both numbers of innovations and total spending, especially the latter. Another is the degree to which innovating firms were able to finance their major innovations with their own, internal resources. Not only was a clear majority of all innovations fully funded internally, but in two of the five industries surveyed, well over half of the necessary funds of innovations requiring some external funding was generated internally, and in a third industry the internally generated proportion was 40 per cent of the total cost. When we consider the firms together with their parents and affiliates as a single source of funding, only in one industry -- smelting and refining -- did the "corporate family" fail to provide at least 65 per cent of total funding.

A third quite general feature is the relative unimportance of the banking system as a source of funding of major innovations. Only in one industry -- again, smelting and refining -- was it important to the funding of those innovations not wholly funded internally. A related general feature is the utter lack of importance -- to all the industries -- of the bond market and of venture capital firms as sources of funding of major innovations.

A final fairly general feature to be noted is the importance of government as a source of funding of major innovations. Once again the smelting and refining industry provides the exception; but in the other four industries government played a distinctly significant role both in terms of the proportion of innovations that it supported and in the average proportion of total funding of the supported innovations that it provided. Of the total innovations in these four industries that required some external funding, the proportions that received some government funding ranged from 48 per cent to 65 per cent. The average percentage of the total funding of these supported innovations that came from government ranged from 27 per cent to 38 per cent. When these proportions and percentages are viewed within the much wider context of all 263 major innovations in these five industries for which sources-of-funding information was provided (including those wholly funded internally), they naturally diminish substantially. But they tend, on the whole, to retain, even then, a degree of significance that is worth noting.

Chapter IX

THE NATURE AND DIRECTION OF TECHNOLOGICAL CHANGE: 1960s VS. 1970s

One final issue to be analysed with respect to technological change over the 1960-79 period relates to the question of whether our data can isolate any important changes which might be occurring over time.

Changes in the Basic Characteristics of Innovations

For the five industries together, process innovations as a proportion of total reported innovations tended to decline through to 1976, but increased in the 1976-79 period. The ratio of process innovations to total innovations was higher in the 1960s (34 per cent) than in the 1970s (27 per cent), but this primarily reflects the relatively small number of process innovations introduced in the 1971-75 period. Thus there is no strong trend towards product innovations over the period as a whole, and this is also true at the industry level.

Table 1

TIME DISTRIBUTION OF PRODUCT AND PROCESS INNOVATIONS

First Launch or Use	Product Innovations		Process Innovations	
	No.	% of Total	No.	% of Total
Pre-1965	16	52	15	48
1965-70	44	73	16	27
1971-75	56	81	13	19
1976-79	84	69	38	31

We can also examine the time distribution of innovations in terms of new vs. improved innovations (Table 2). The data for all innovations taken together show no strong trend towards either increasing reliance on product and process improvements or on the development of new products and processes.

Table 2

NEW VS. IMPROVED INNOVATIONS OVER TIME

First Launch or Use	No. of New Innovations	No. of Improved Innovations	Total	New as % of Total
Pre-1965	20	15	35	57
1965-70	35	21	56	63
1971-75	44	25	69	64
1976-79	71	51	122	58

In respect of new vs. improved innovations, the behaviour of specific industries over time is more varied and is presented in Table 3 below. Firms in the telecommunications equipment industry produce the highest proportion of new products as opposed to improved products, but there is a clear tendency towards reliance on product improvement innovations in the 1970s as compared to the 1960s. Interestingly enough, just the opposite is true of electrical industrial products, since we find a strong tendency over time to develop new as opposed to improved innovations in this industry. In the other three industries, new innovations increased as a proportion of total innovations in the 1971-75 period and then declined in the 1976-79 period. Thus, there is a tendency in all the industries except electrical industrial equipment towards improvement type innovations and away from the development of new product and process innovations in the latter half of the 1970s. When product and process innovations are examined separately in terms of new vs. improved innovations, the same trends emerge at the industry level.

Table 3

NEW VS. IMPROVED INNOVATIONS OVER TIME, BY INDUSTRY

Industry	New Innovations (No.)	Improved Innovations (No.)	New As % of Total
Telecommunications Equipment and Components			
Pre-1971	26	4	87
1971-75	21	7	75
1976-79	35	15	70
Electrical Industrial Equipment			
Pre-1971	5	12	29
1971-75	9	11	45
1976-79	16	15	52
Plastics Compounds and Synthetic Resins			
Pre-1971	9	8	53
1971-75	9	3	75
1976-79	7	4	63
Smelting and Refining			
Pre-1971	10	3	77
1971-75	1	0	100
1976-79	9	10	47
Crude Petroleum Production			
Pre-1971	5	8	38
1971-75	4	3	57
1976-79	3	6	33

In addition to these tests, we examined the period of time being devoted to the development of product and process innovations by firms to determine whether it had, on average, been growing shorter.

Table 4

MEDIAN NUMBER OF MONTHS TO DEVELOP INNOVATIONS OVER TIME, BY TYPE OF INNOVATION

Time	All Innovations		Product Innovations		Process Innovations	
	No. of Innovations	Median No. of Months	No. of Innovations	Median No. of Months	No. of Innovations	Median No. of Months
Pre-1965	31	14	16	10	15	21
1965-70	58	18	43	18	15	21
1971-75	68	18	55	18	13	20
1976-79	113	16	82	14	36	24

There is no strong tendency for the amount of time devoted to the development of innovations by firms to shorten in the 1970s as compared to the 1960s, although the median number of months devoted to the development of product innovations does fall in the 1976-79 period relative to the 1965-75 period.

It has been suggested that firms may have tended to shift their attention to shorter-term innovations, i.e., innovations with faster pay-back periods on their R&D investments. The following table examines the changes in pay-back period for reported product and process innovations over time.

Table 5

TIME DISTRIBUTION OF INNOVATIONS, PAY-BACK PERIOD

Time	No. of Innovations	% of Innovations with Pay-Back Period of:		
		Less than 3 Years	3-5 Years	More than 5 Years
			-- (%) --	
Product Innovations				
Pre-1971	57	51	37	12
1971-75	55	42	31	27
1976-79	77	68	26	7
Process Innovations				
Pre-1971	30	47	27	27
1971-75	10	50	30	20
1976-79	33	58	27	15

Our data do show that there has been a movement towards innovations with faster pay-backs for both product and process innovations in the latter half of the 1970s. The proportion of product innovations with a pay-back period of less than 3 years fell in the first half of the 1970s but then rose sharply in the 1976-79 period. This movement was mirrored in respect of the proportion of innovations with long pay-back periods, which declined from 27 per cent of the total in the 1971-75 period to only 7 per cent in the 1976-79 period. In respect of process innovations, the trend towards innovations with more rapid pay-backs is evident even in the 1971-75 period. As a result of these trends, 68 per cent of all product innovations and 58 per cent of all process innovations introduced in the latter half of the 1970s had pay-back periods of less than 3 years. As is demonstrated in Table 6, this tendency was pervasive in all the five industries.

Table 6

PAY-BACK PERIODS OVER TIME, BY INDUSTRY

Industry	No. of Innovations	% of Innovations With Pay-Back Period of: Less than 3 Years	3-5 Years	More than 5 Years
			-- (%) --	
Telecommunications Equipment and Components				
Pre-1971	29	52	34	14
1971-75	28	50	29	21
1976-79	45	60	31	9
Electrical Industrial Equipment				
Pre-1971	16	50	38	13
1971-75	20	40	35	25
1976-79	29	72	24	3
Plastics Compounds and Synthetic Resins				
Pre-1971	16	63	31	6
1971-75	10	40	40	20
1976-79	10	80	10	10
Smelting and Refining				
Pre-1971	13	38	54	8
1971-75	0	0	0	0
1976-79	17	65	29	6
Crude Petroleum Production				
Pre-1971	12	42	8	50
1971-75	6	33	17	50
1976-79	7	43	29	29

Another aspect of the changing nature of innovations over time is the tendency of firms in Canada to produce innovations based on other important innovations being launched or introduced into production processes around the world -- i.e., imitative innovations. In Table 7 is set out the proportion of total innovations which are imitative and original (first launched or used by the reporting firms).

Table 7

ORIGINAL VS. IMITATIVE INNOVATIONS OVER TIME, BY TYPE OF INNOVATION

Time	Originals			Imitations			Imitations as a % of Total		
	All	Product	Process	All	Product	Process	All	Product	Process
		-- (No.) --			-- (No.) --			-- (%) --	
Pre-1965	17	8	9	13	7	6	43	47	40
1965-70	31	24	7	29	20	9	48	45	56
1971-75	40	32	8	28	23	5	41	42	32
1976-79	59	44	15	63	40	23	52	48	61

Again, there is no great change in the proportion of innovations which are imitative of innovations originally developed elsewhere, but in the latter half of the 1970s reported innovations, especially processes, tend to be based more often on innovations being developed around the world than in earlier periods. In fact, in light of the increasingly competitive world environment on the trade and technology side, one might have expected to see a stronger long-run trend over time in the proportion of innovations imitating ones already introduced abroad. Again, it should be stressed that the distinction between original and imitative innovations does not indicate where the technology for the innovation is developed (in-house or external acquisition). In fact, we have seen that over half of the imitative innovations are based on technology developed in-house. The source of technology issue is discussed at length further below.

Another test of the changing nature of innovations over time relates to their impact on the skill requirements of the labour force involved in the manufacture of the new or improved products or in the application of the new or improved processes. The proportion of innovations where the labour force skill requirements of the work force were raised as a result of the innovations is presented in Table 8.

Table 8

PROPORTION OF INNOVATIONS WHERE
LABOUR FORCE SKILL REQUIREMENTS WERE RAISED
OVER TIME AND BY TYPE OF INNOVATION

	All Innovations		Product Innovations		Process Innovations	
Time	No.	% Where Skill Requirements Raised	No.	% Where Skill Requirements Raised	No.	% Where Skill Requirements Raised
Pre-1965	31	87	16	94	13	80
1965-70	59	68	43	65	16	75
1971-75	68	76	56	76	12	75
1976-79	119	66	82	71	37	57

A quite high percentage of innovations had the effect of raising the skill requirements of the labour force employed, as would be expected given that firms are reporting on their major innovations. However, there appears to be a tendency for the proportion of innovations resulting in higher skill requirements to decline over the period, although the downward trend is again interrupted in the 1971-75 period. In the latter half of the 1970s, the proportion of innovations requiring increased skill on the part of the labour force fell to 66 per cent, and the proportion for process innovations falls particularly sharply (to 57 per cent). This trend is taken to indicate a tendency for innovations to become less radical, especially in the latter half of the 1970s, and is consistent with the earlier findings set out above in respect of pay-back periods and improvement innovations.

To summarize to this point, there is evidence of a somewhat unfavourable alteration of the direction of technological change in the latter half of the 1970s. There is evidence of a tendency to move towards improvement innovations and away from new product and process developments in most of the industries under examination. Furthermore, there is a marked increase in the proportion of innovations with relatively short pay-back periods in the latter half of the 1970s and a corresponding decrease in the proportion of innovations with pay-back periods in excess of 5 years. Also, the proportion of innovations which had the effect of raising the skill requirements of the labour force declined in respect of innovations introduced in the latter half of the 1970s. Finally, as noted in Chapter VII, the proportion of innovations being patented declined in the 1970s. Therefore, we do find some support for the view that the problems and uncertainties generated by our poorer economic performance in the 1970s at the economy-wide level was affecting the direction of technological change in the latter half of the 1970s in an undesirable manner.

Changes in Average Expenditures on Innovations

We have stressed in earlier chapters that innovation is an extremely expensive proposition for most firms. The following table sets out the average costs (in current dollars) of the major product and process innovations of reporting firms over the 1960-79 period.

If we examine the median values of total expenditures for all innovations over each of the time periods, we see a sharp decline in median expenditures in the 1976-79 period. This is true of both product and process innovations. In addition, the median value of total

Table 9

AVERAGE TOTAL EXPENDITURES ON INNOVATIONS
OVER TIME, BY TYPE OF INNOVATION

Time	All Innovations			Product Innovations			Process Innovations		
	No.	Mean	Median	No.	Mean	Median	No.	Mean	Median
					-- ($'000) --				
Pre-1965	26	5,373	370	14	363	120	12	11,218	233
1965-70	45	1,876	310	33	1,357	233	12	3,303	1,900
1971-75	56	933	310	46	634	300	10	2,307	400
1976-79	107	3,316	161	76	693	150	31	9,747	277

expenditures on process innovations in the 1971-75 period is considerably lower than median value for the 1965-70 period. The decline in median total expenditures is a particularly surprising result, as one would have thought the effect of inflation alone on costs of innovating would give a strong upward trend to the expenditures data over time. On the other hand, the mean values for total expenditures on all innovations present a different picture -- the mean expenditures on innovations fall, through to 1976, and then increase in the 1976-79 period. The main reason for this latter result is that there were a very small number of extremely costly innovations (particularly process) introduced in the 1976-79 period which pull mean expenditures up very sharply. Thus we conclude that even in current dollars there is a tendency for total expenditures on innovations to decline in the 1976-79 period on average but, even so, 5 of the 31 process innovations introduced during this period each required total expenditures in excess of $25 million. However, these findings could be the result of changes in industrial mix of the innovations over time.

The following table examines average expenditures on innovations by industry, comparing the 1965-75 period with the 1976-79 period for product and process innovations.

Table 10

TOTAL EXPENDITURES ON INNOVATIONS OVER TIME, BY TYPE OF INNOVATION AND INDUSTRY

Industry	All Innovations			Product Innovations			Process Innovations		
	No.	Mean	Median	No.	Mean	Median	No.	Mean	Median
					-- ($'000) --				
Telecommunications Equipment and Components									
1965-75	42	682	290	37	618	278	5	1,156	311
1976-79	49	623	189	45	563	150	4	1,303	280
Electrical Industrial Equipment									
1965-75	23	451	235	20	494	320	3	166	39
1976-79	24	944	130	21	1,073	156	3	41	12
Plastics Compounds and Synthetic Resins									
1965-75	23	904	213	19	744	73	4	1,664	1,030
1976-79	11	12,169	138	6	297	60	5	26,415	420
Smelting and Refining									
1965-75	5	10,182	11,230	2	12,380	9,510	3	8,717	6,575
1976-79	15	8,163	650	3	983	225	12	9,958	900
Crude Petroleum Exploration and Production									
1965-75	7	3,376	1,075	0	--	--	7	3,376	1,075
1976-79	7	6,465	86	0	--	--	7	6,465	86

The overall trends isolated in respect of all innovations are pervasive at the industry level. Median values for product and process innovations decline in the 1976-79 period. Again, large mean values for some industrial innovations in the latter half of the '70s indicate the presence of a few extremely large and costly innovations, but the overall trend in respect of spending by firms on major innovations is clearly downwards. This finding is consistent with the earlier analysis which found a tendency for firms to turn to innovations with quicker pay-backs,etc.

Finally, we examine total expenditures on innovations over time by size of firm, since a larger proportion of small firms were reporting innovations in the 1970s compared to the 1960s and this would likely affect average total expenditure values on innovations. When we examine total expenditures over time by size of firm we find that for smaller firms (100 or less employees) the median values still exhibit a marked downward trend over the 1970s as compared to the 1960s (Table 11).

Table 11

AVERAGE TOTAL EXPENDITURES ON INNOVATIONS
OVER TIME, BY SIZE OF FIRM AND TYPE OF INNOVATION

No. of Employees	All Innovations			Product Innovations			Process Innovations		
	No.	Mean	Median	No.	Mean	Median	No.	Mean	Median
					-- ($'000) --				
0-100									
Pre-1971	18	591	200	13	353	142	5	1,209	200
1971-79	77	457	100	65	249	100	12	1,583	61
101-500									
Pre-1971	33	1,709	183	24	336	120	9	5,369	588
1971-79	55	3,572	400	42	858	380	13	12,341	560
Over 500									
Pre-1971	18	8,631	1,900	9	4,004	1,525	9	13,258	1,550
1971-79	28	30,939	1,500	13	31,006	1,075	15	30,881	1,750

In fact, the only size category which exhibits a strong increase in average expenditures on innovations is the product innovations of medium sized firms (median values for their process innovations decline slightly). For large firms, median expenditures on product innovations decline but expenditures on process innovations increase slightly. Thus, even when we control for size, the general tendency towards declining average expenditures on innovations in the 1970s persists. Again, the high mean values for some categories of innovations indicate the presence of a small number of very expensive innovations. Of course, the general tendency towards the production of less costly innovations would be more marked if the expenditure values were deflated.

Changes in Innovation Spending Profiles

In an analysis of the changing nature of the innovations, an important indicator of possible changes is the profile of expenditures on innovations over time. The profiles for product and process innovations are set out in Table 12.

Table 12

AVERAGES OF RATIOS OF EXPENDITURES BY STAGE
TO TOTAL EXPENDITURES PER INNOVATION OVER TIME:
PRODUCT VS. PROCESS INNOVATIONS

Stage	Pre-1965			1965-70			1971-75			1976-79		
	All	Product	Process	All	Product	Process	All	Product	Process	All	Product	Process
	(26)	(14)	(12)	(45)	(33)	(12)	(57)	(46)	(11)	(109)	(77)	(32)
						-- % --						
Basic Research	4.0	3.9	4.1	4.3	4.5	3.5	9.3	10.6	3.5	6.1	7.1	3.6
Applied Research	6.9	7.6	6.0	10.4	10.0	11.5	19.5	17.5	27.4*	12.4	11.9	13.6
Development	38.7	45.7	30.5	32.3	34.7	25.6	40.7	39.8	44.6	41.9	48.0	27.1
(R&D)	(49 6)	(57.2)	(40.7)	(46.9)	(49.1)	(40.6)	(69.4)	(63.0)	(75.5)	(60.4)	(67.0)	(44.3)
Manufacturing Start-Up	46.0	39.1	54.0	42.6	37.0	57.7	22.5	23.7	22.6	32.5	23.5	54.2
Marketing Start-Up	4.5	3.7	5.3	10.6	13.8	1.8	7.0	8.3	1.9	7.1	9.5	1.5

*Because there are only 11 cases in this class, one innovation with 88 per cent of its expenditures classified as Applied Research is strongly affecting the results. If this innovation is deleted, the Applied Research ratio falls sharply but remains higher than in earlier periods.

There is a clear tendency for the R&D component of spending on innovations to rise and the manufacturing start-up to fall over time. The rise in the R&D component primarily reflects increased relative spending on research in the process of generating new and improved products and processes in the 1970s. At the same time, manufacturing start-up costs decline in relative importance, no doubt reflecting to a degree the tendency towards innovations requiring smaller total expenditures. In addition, the decreasing reliance on imported technology plays an important role in explaining the growing relative importance of R&D, particularly research expenditures, in the total costs of innovating. The tendency for R&D expenditures as a proportion of total expenditures to rise is also evident at the industry level. Relative R&D spending for all product innovations increases in the 1970s relative to the 1960s, and the same is true of process innovations, except in the smelting and refining industry where the R&D component decreases in the 1970s.

Changing Sources of Technology for Innovations

We have seen in Chapter III that the importation of technology has quite strong effects on the relative spending profiles of firms' innovations. Over the 1960-79 period, there was a marked tendency to increasingly rely on the in-house development of the technologies forming the basis of our industrial innovations. Innovations developed in Canada which have relied primarily on imported technology have declined over time for both product and process innovations (Table 13). Reliance on imported technology was particularly low in the 1971-75 period. The trend towards increasing reliance on domestically developed technology plays an important role in explaining the rising proportion of research particularly, and of R&D spending in total, in the expenditure profiles of our innovations over time.

Table 13

SOURCES OF TECHNOLOGY FOR PRODUCT AND PROCESS INNOVATIONS

Time	Total No. of Innovations	Primary Source of Technology: In-House Product	In-House Process	External Only Product	External Only Process	Both Product	Both Process	External Only as % of Total
Pre-1965	31	10	9	5	5	1	1	32
1965-70	60	23	7	20	7	1	2	45
1971-75	69	50	4	5	4	1	5	13
1976-79	122	65	19	17	13	2	6	25

In Table 14 are set out the average spending ratios for innovations where the technology source was primarily external and for innovations where the technology was primarily developed in-house for the 1960s as compared to the 1970s. These data demonstrate that even when we control for source of technology, the tendency towards increasing relative spending on R&D persists. In fact, it is very pervasive. Research spending, as a proportion of total spending rises sharply for both those innovations utilizing technology developed in-house and those utilizing imported technology. The same is true for relative R&D spending in total, except that the relative R&D spending on process innovations based on imported technology (which in any case is very low) actually declines a little in the 1970s.

Table 14

AVERAGE OF RATIOS OF SPENDING BY STAGE TO TOTAL SPENDING PER INNOVATION BY SOURCE OF TECHNOLOGY: 1960s VS. 1970s, BY TYPE OF INNOVATION

	Pre-1971				1971-1979			
	Product Innovations		Process Innovations		Product Innovations		Process Innovations	
Stage	External	In-House	External	In-House	External	In-House	External	In-House
	(18)	(28)	(8)	(13)	(18)	(102)	(14)	(20)
Basic Research	1.0	6.6	0	5.1	2.7	9.3	0	6.7
Applied Research	2.7	13.8	0.7	14.1	10.3	15.1	9.3	16.4
Development	34.8	38.9	38.4	25.0	50.6	43.8	24.9	32.9
(RD&)	(38.6)	(59.3)	(39.1)	(44.2)	(63.5)	(68.2)	(36.2)	(56.0)
Manufacturing Start-Up	41.5	35.7	60.7	49.5	28.9	22.5	63.2	43.5
Marketing Start-Up	19.9	5.0	0.2	6.3	7.6	9.3	2.6	0.5

In summary, the marked tendency for the R&D components of total spending on innovations to increase is not by any means wholly explained by the shift towards reliance on technologies developed in-house in the 1970s. Of course, the increase in the R&D components is accompanied by a decrease in the relative importance of manufacturing start-up costs. Therefore, these relative shifts in the components of spending on the major innovations are being influenced by the tendency in the 1970s to develop smaller, less costly innovations.*

Changes in the Nature of Innovations of Canadian- and Foreign-Controlled Firms Over Time

The proportion of total reported innovations accounted for by Canadian-controlled firms has increased when the 1960s are compared to the 1970s. This increase was particularly noticeable in the first half of the 1970s when innovations introduced by Canadian-controlled firms rose to 51 per cent of the total innovations introduced during that period.

Table 15

INNOVATIONS BY ORIGIN OF CONTROL

Time	Number of Innovations: Canadian-Controlled	Number of Innovations: Foreign-Controlled	Canadian-Controlled as % of Total
Pre-1971	30	61	33
1971-75	35	34	51
1976-79	56	66	46

At the same time, both Canadian- and foreign-controlled firms in the 1970s were increasingly introducing major innovations based on technologies which they had developed in-house.

*When we control for the cost of the innovations, the strong tendency towards higher R&D components in the 1970s is weakened and even reversed in some cases. But the strong tendency towards a higher R&D component still persists for small and medium-sized product innovations and for medium-sized process innovations.

Table 16

NUMBER OF INNOVATIONS, BY ORIGIN OF CONTROL AND SOURCE OF TECHNOLOGY

Source of Technology	Canadian-Controlled Innovations						Foreign-Controlled Innovations					
	Pre-1971		1971-1975		1976-1979		Pre-1971		1971-1975		1976-1979	
	No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total
Innovations based on Technology:												
-Externally Acquired	7	23	1	3	6	11	30	49	8	24	24	36
-Developed In-House	20	67	32	91	47	84	29	48	22	65	37	56
-Combination	3	10	2	6	3	5	2	3	4	12	5	8

The trend toward greater reliance on innovations using technology developed in-house was particularly strong in the first half of the 1970s. But even in the 1976-79 period innovations primarily based on imported technology represented only 11 per cent of the innovations of Canadian-controlled firms and 36 per cent of those of foreign-controlled firms.

In conjunction with the tendency toward a decreased reliance on imported technology, it is interesting to examine the trend in the development of original and imitative innovations over time by origin of control. In Table 17, it can be seen that product innovations of Canadian-controlled firms tended over time to more often imitate innovations developed abroad. This is in contrast to product innovations of foreign-controlled firms, which show a tendency toward the development of more original innovations in the 1970s as compared to the 1960s; there is a sharp increase in the proportion of original innovations in the first half of the 1970s, followed by a return to the 1960s level in the second half of the 1970s. On the other hand, process innovations by Canadian- and foreign-controlled firms show similar trends -- an increase in the proportion of original process innovations in the first half of the 1970s and then a decline in the last half of the 1970s. If we compare the first and second halves of the 1970s, we see a general trend towards increased reliance on imitative innovations, particularly in respect of process innovations,

Table 17

ORIGINAL VS. IMITATIVE INNOVATIONS OVER TIME BY ORIGIN OF CONTROL

	Original Innovations				Imitative Innovations			
	No. of Product Innovations		No. of Process Innovations		No. of Product Innovations		No. of Process Innovations	
Time	Canadian-Controlled	Foreign-Controlled	Canadian-Controlled	Foreign-Controlled	Canadian-Controlled	Foreign-Controlled	Canadian-Controlled	Foreign-Controlled
Pre-1971	13	19	5	11	5	22	6	9
1971-75	20	12	2	6	12	11	1	4
1976-79	26	18	5	10	19	21	6	17
	Canadian-Controlled Product Innovations		Foreign-Controlled Product Innovations		Canadian-Controlled Process Innovations		Foreign-Controlled Process Innovations	
	No.	% Original	No.	% Original	No.	% Original	No.	% Original
Pre-1971	18	72	41	46	11	45	20	55
1971-75	32	63	23	52	3	67	10	60
1976-79	45	58	39	46	11	45	27	37

for both Canadian- and foreign-controlled firms. Over the longer period, no clear trend emerges except in respect of Canadian product innovations which are becoming increasingly imitative. Thus the trend toward increased reliance on internally developed technology is not, in general, reflected in a trend towards more original innovations. Instead, imitation of innovations via the development of the required technology in-house is becoming increasingly important over time.

We can also compare the size of Canadian- and foreign-controlled firms' innovations over time in terms of total expenditures per innovation (Table 18).

Table 18

TOTAL EXPENDITURES BY FIRMS ON INNOVATIONS OVER TIME, BY TYPE OF INNOVATION AND ORIGIN OF CONTROL

	Canadian-Controlled Innovations						Foreign-Controlled Innovations					
	Product Innovations			Process Innovations			Product Innovations			Process Innovations		
Time	No.	Mean	Median	No.	Mean	Median	No.	Mean	Median	No.	Mean	Median
						-- ($'000) --						
Pre-1971	15	946	40	10	2,655	565	32	1,115	270	14	10,550	950
1971-75	24	407	245	2	230	110	22	881	366	8	2,827	650
1976-79	39	450	136	10	223	20	37	950	188	21	14,282	1,090

Both the mean and median expenditures of Canadian-controlled firms decline in the latter half of the 1970s in respect of both product and process innovations. The same is true for the product innovations of foreign-controlled firms. However, the median values for process innovations by foreign-controlled firms does not change much. Therefore, the comparison of expenditures on innovations by origin of control also demonstrates the general tendency for expenditures on innovations to decline in the 1976-79 period, particularly in respect of product innovations, for both types of firm and for the process innovations of Canadian-controlled firms. The result is that foreign-controlled firms continue to spend relatively more on their innovations, and the difference between Canadian-controlled and foreign-controlled firms widens in respect of process innovations.

With regard to the spending profiles of product and process innovations by control, the data in Table 19 again show the tendency for the R&D component of innovation to rise and the manufacturing start-up component to fall for both Canadian- and foreign-controlled firms' innovations, when the 1960s are compared to the 1970s. The exception to this general trend is in respect of process innovations by foreign-controlled firms, since the R&D component on these innovations falls below all previous periods' levels in the 1976-79 period. The product innovations of Canadian- and foreign-controlled firms have very similar profiles in the 1960s. In the 1970s, the R&D component rises and the manufacturing start-up component falls for these innovations, but the movements are stronger in the case of Canadian-controlled firms' innovations. These movements are being strongly influenced by the declining absolute and relative size of the innovations of Canadian-controlled firms in the 1970s.

Table 19

AVERAGE OF RATIOS OF SPENDING BY STAGE TO TOTAL SPENDING PER INNOVATION OVER TIME, BY TYPE OF INNOVATION AND ORIGIN OF CONTROL

	Product Innovations					
	Pre-1971		1971-1975		1975-79	
Stage	Canadian-Controlled	Foreign-Controlled	Canadian-Controlled	Foreign-Controlled	Canadian-Controlled	Foreign-Controlled
	(15)	(32)	(24)	(22)	(39)	(38)
			-- (%) --			
Basic Research	7.1	3.0	13.9	7.1	9.1	5.0
Applied Research	9.2	9.3	18.7	16.3	14.5	9.3
Development	34.8	39.4	39.9	39.6	46.9	49.2
R&D	51.2	51.7	72.6	63.0	70.4	63.5
Manufacturing Start-Up	44.2	34.6	18.6	29.4	18.4	28.6
Marketing Start-Up	4.6	13.7	8.9	7.6	11.1	7.9
	Process Innovations					
	(10)	(14)	(3)	(8)	(10)	(22)
			-- (%) --			
Basic Research	4.5	3.3	0	4.9	9.4	1.0
Applied Research	9.2	8.4	22.1	29.3	14.7	13.1
Development	25.8	29.7	38.1	47.0	42.3	20.2
R&D	39.5	41.5	60.2	81.2	66.4	34.3
Manufacturing Start-Up	54.0	57.2	35.1	18.0	32.6	64.0
Marketing Start-Up	6.5	1.4	4.8	0.8	1.0	1.7

In respect of process innovations, the spending profiles of Canadian- and foreign-controlled firms are also quite similar in the 1960s. In the first half of the 1970s, the R&D component of both types of firms' innovations rises, the rise being particularly steep for foreign-controlled firms' innovations. In the latter half of the 1970s, the R&D component of Canadian-controlled firms' innovations rises a little further, but the R&D component of the process innovations of foreign-controlled firms falls sharply, accompanied by a strong increase in the manufacturing start-up spending component. Again, the total spending on process innovations by Canadian firms, on average, declined sharply in the 1976-79 period, while that by foreign-controlled firms rose to levels higher than in all previous periods.

Finally, we can examine the performance indicators for different types of innovations in the 1960s and 1970s separately to determine whether the trends in the nature of the innovations discussed above have affected performance. Again, most of our performance indicators are product innovation-based.

In general, the export performance indicators for the product innovations of reporting firms show some rather mixed trends (Table 20). The percentage of product innovations being exported in 1978 does not change much when the innovations introduced in the 1960s are compared with those introduced in the 1970s. Similarly, the tendency for the product innovations of Canadian-controlled firms to more often be associated with exports than those of foreign-controlled firms does not change. As pointed out earlier, this difference is the result of the low association between innovations based on imported technology and exportation, coupled with the higher percentage of foreign-controlled firms' innovations based on imported technology. However, when we look at the median percentage of sales arising from exports of product innovations in 1978, we find a significant change between the 1960s and 1970s. The median percentage of sales of the product innovations of foreign-controlled firms introduced in the 1960s which were being exported in 1978 was only 20 per cent (as compared to 60 per cent for Canadian-controlled firms' innovations), but in respect of innovations introduced in the 1970s the percentage rises to 76 per cent cent (as compared to a decline to 50 per cent for Canadian-controlled firms). Thus in the 1970s, a very high proportion of the sales of the product innovations of foreign-controlled firms were being exported (in respect of those product innovations which were being exported).

Table 20

EXPORT PERFORMANCE INDICATORS,
BY PERIOD OF INTRODUCTION OF PRODUCT INNOVATIONS

Performance Indicator	Pre-1971 No.	Pre-1971 %	1971-78 No.	1971-78 %
Percentage of Product Innovations Associated with Exports in 1978				
All Product Innovations	47	60	98	62
Canadian-Controlled	9	67	53	68
Foreign-Controlled	38	57	45	56
Externally Acquired Technology	21	48	14	36
Technology Developed In-House	26	69	83	66
Average Percentages Exported	No.	Median (%)	No.	Median (%)
All Product Innovations	28	38	61	65
Canadian-Controlled	6	60	36	50
Foreign-Controlled	22	20	25	76
Externally Acquired Technology	10	3	5	5
Technology Developed In-House	18	50	55	68
Average Export Values	No.	Median ($000)	No.	Median ($000)
All Product Innovations	28	500	61	347
Canadian-Controlled	6	720	36	250
Foreign-Controlled	22	400	25	775
Externally Acquired Technology	10	210	5	55
Technology Developed In-House	18	720	55	375

However, the median export values of product innovations in 1978 decline when the innovations introduced in the 1970s are compared to those introduced in the 1960s. To a large extent this reflects the fact that the more recently introduced innovations have not yet found their full market potential abroad, but may also reflect the declining size of the innovations over time. However, in respect of the 1978 export values of the product innovations of foreign-controlled firms, we find a significant increase in the 1970s, contrary to the trend for all the other types of innovations. This is the result of the finding that a significantly higher percentage of the sales generated by these innovation in the 1970s were being exported.

The sales performance indicators for product innovations appear to show a deteriorating trend in the 1970s. However, the generally smaller median 1978 sales value of the innovations introduced in the 1970s probably reflects their recent vintage to a large extent -- i.e., they have not yet fulfilled their market potential. This effect clearly outweighs any tendency for innovations in the 1960s to become obsolete in the 1970s. Nevertheless, the decline in median expenditures on innovations in the 1970s may be playing a role here as well. The relative performance of the different types of innovations does not change significantly over time in respect of 1978 sales values of the innovations. Product innovations by foreign-controlled firms, on average, have much higher sales values in 1978 than those of Canadian-controlled firms. However, the sales performance of innovations based on imported technology was superior to that of innovations based on in-house technology in the 1960s, but inferior to the sales performance of innovations based on in-house technology in the 1970s.

Table 21

SALES PERFORMANCE INDICATORS,
BY PERIOD OF INTRODUCTION OF PRODUCT INNOVATIONS

Median 1978 Sales Values of Product Innovations	Pre-1971		1971-1978	
	No.	Median	No.	Median
		-- ($'000) --		
All Product Innovations	47	1,825	98	800
Canadian-Controlled	9	892	51	475
Foreign-Controlled	38	2,000	47	1,000
Externally Acquired Technology	21	1,825	14	500
Technology Developed In-House	26	1,600	83	831

Table 22 sets out information on the percentage of innovations which led to further research and development work and innovation (spin-offs) for the different types of innovations in the 1960s and 1970s. The proportion of innovations giving rise to spin-offs rises for Canadian-controlled firms but falls for foreign-controlled firms because the ratio for innovations based on imported technology declines very sharply in the 1970s.

Table 22

PERCENTAGE OF INNOVATIONS LEADING TO SPIN-OFFS,
BY PERIOD OF INTRODUCTION OF THE INNOVATIONS

Type	Pre-1971	1971-1979
	-- (%) --	
All Innovations	71	70
Canadian-Controlled	66	76
Foreign-Controlled	74	63
Externally Acquired Technology	61	49
Technology Developed In-House	78	75

Finally in Table 23 we compare the percentage of innovations raising the skill requirements of the labour force for innovations introduced in the 1970s with those introduced in the 1960s. Again, the proportion of innovations raising skill requirements declines for innovations based on imported technology, and thus pulls down the ratio for the innovations of foreign-controlled firms.

Table 23

PERCENTAGE OF INNOVATIONS RAISING SKILL REQUIREMENTS OF THE LABOUR FORCE, BY PERIOD OF INTRODUCTION OF THE INNOVATION

Type	Pre-1971	1971-79
	-- (%) --	
All Innovations	74	70
Canadian-Controlled	72	71
Foreign-Controlled	75	69
Externally Acquired Technology	78	66
Technology Developed In-House	69	71

Summary

There have been some significant changes in the nature and direction of innovation and technological change processes in the five Canadian industries in the 1970s, particularly in the latter half of the 1970s. The main findings are set out below.

There is evidence of a movement away from the development of new innovations toward the development of improvement innovations in the latter half of the 1970s. Although both types of innovations are important aspects of the innovation process, an increasing reliance on improvement innovations could reflect an unwillingness to attempt more radical innovations.

There is a strong movement in the latter half of the 1970s toward innovations with more rapid pay-backs.

The proportion of innovations which raised the skill requirements of the labour force fell very sharply for innovations introduced in the latter half of the 1970s, particularly for process innovations.

There is also evidence of a tendency for expenditures on major innovations to decline, on average, in the 1970s, particularly in the latter half of the 1970s. The tendency would be stronger had the expenditures been measured in constant rather than current dollars. Median expenditures on product innovations for both Canadian- and foreign-controlled firms declined in the latter half of the 1970s. The same is true for the process innovations of the Canadian-controlled firms. However, the median expenditures on process innovations by foreign-controlled firms rose in the latter half of the 1970s relative to earlier periods. Over time, the foreign-controlled firms continued to spend more on their innovations than the Canadian-controlled firms, on average, and the difference widened in respect of process innovations in the 1970s.

The R&D component of spending on major innovations increased, and the manufacturing component declined in the 1970s as compared to the 1960s. However, this also reflects, to a large extent, the declining size of the innovations being undertaken (though it is additionally influenced by a decline in the proportion of innovations based on imported technologies).

As discussed in Chapter VII, the proportion of major innovations being patented in Canada declined in the 1970s.

The above trends are evidence of a deterioration in the nature and direction of innovation and technological change processes, particularly in the latter half of the 1970s. These findings are consistent with the view that the problems and uncertainties generated by our poorer macro-economic performance in the 1970s in terms of both growth and price stability was affecting the nature and direction of technological change in an undesirable manner.

On the other hand, some of the trends in other aspects of the innovation process in the 1970s are suggestive of a strengthening in the technological bases of the industries being examined.

The proportion of innovations introduced in the latter half of the 1970s which were in imitation of major innovations introduced abroad increased, particularly for process innovations. At the same time, the proportion of all innovations of the reporting firms utilizing externally acquired technology declined noticeably in the 1970s. The result was that in the 1970s, the reporting firms in Canada were demonstrating an increased ability to employ the technologies they developed in-house when imitating major innovations already introduced abroad.

In the 1970s, larger proportions of the innovations of both Canadian- and foreign-controlled firms were based on technologies developed in-house. Only 20 per cent of the reported innovations had externally acquired technologies as their sole primary source as compared to 41 per cent in the 1960s. Therefore, both Canadian- and foreign-controlled firms were increasingly demonstrating the ability to develop their technologies internally when imitating major innovations already introduced abroad.

Finally, the performance indicators for reported innovations do not change much over time, although there are some important shifts for specific types of firms and innovations.

The percentage of product innovations being exported in 1978 changes little when the innovations introduced in the 1960s are compared to those introduced in the 1970s. However, for those innovations which were being exported in 1978, the average percentage of sales accounted for by exports rose sharply for innovations introduced in the 1970s because the foreign-controlled firms had sharply higher export to sales ratios for their more recent innovations. The ratio actually declines a little for Canadian-controlled firms. As a result, the average value of exports in 1978 of foreign-controlled firms for their product innovations introduced in the 1970s rose very sharply (and the value for Canadian-controlled firms declined).

The median values of sales in 1978 of the product innovations introduced in the 1970s declined for all the types of innovations analysed. This parallels the decline in average expenditures on the development of these innovations.

The proportion of innovations giving rise to spin-offs in the 1970s does not change much because the proportion rises for Canadian-controlled firms and declines for foreign-controlled firms. The decline for foreign-controlled firms results from a decline in the proportion of innovations based on imported technologies which led to spin-offs. The same results are found for the proportion of innovations raising the skill requirements of the labour force in the reporting firms. In general, the more dynamic performance indicators for innovations based on imported technologies deteriorate sharply in the 1970s compared to those in the 1960s.

Chapter X

CONCLUSIONS AND IMPLICATIONS FOR SOME CURRENT INDUSTRIAL POLICY ISSUES

This report has examined many aspects of the nature and direction of technological change processes in five Canadian industries over the last two decades. It was our view that we simply did not have enough reasonably "hard" basic data and information on these processes which are so vital to the long run competitiveness and growth of Canadian firms and industries. Thus one aim of our study was to provide basic information on the nature and characteristics of major Canadian innovations, the sources of the technology for these innovations, their costs and financing, the types of resources required to produce them, the factors influencing their introduction, some of their manpower impacts, whether or not they were being patented, and the types of major problems encountered by the innovating firms. It should be noted that the study focuses on "successes"; it does not examine innovative attempts which failed.

Our survey results describing the nature and characteristics of major innovations are so numerous we will not even attempt to summarize them here*. We would, however, like to highlight briefly a very few of these general findings. Improvement innovations comprised 40 per cent of all major innovations reported, indicating the importance of product and process improvements to the innovation process. In addition, almost half of the reported innovations were in imitation of innovations first developed abroad, indicating the importance of the latter to the technological change process in Canada. Only 27 per cent of all reported innovations were primarily based on technologies developed outside the innovating firm and most of these involved intracorporate MNE transfers. Other outside technology sources were not heavily utilized as primary technology sources for the major innovations of either Canadian- or foreign-controlled firms. In terms of expenditures on innovations, developmental and manufacturing start-up costs have represented the two largest components of spending on innovations, with developmental costs dominating spending on product innovations and manufacturing start-up costs being dominant for process innovations.

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* See the general summary of the report and the chapter-specific summaries.

A second important aim of the study was to isolate patterns in the process of innovation and technological change among industries and types of firms. We found inter-industry variations were strongly influenced by structural factors -- the technology of the industry, the size of the firms in the industry, and the origin of control of the firms. Particular emphasis was placed on the roles of Canadian- and foreign-controlled firms and small and large firms. We discovered some very marked and systematic differences among these firms in respect of a large number of the different aspects of the innovation and technological change processes under examination. To the extent possible, we tried to identify reasons for the differences in the character of the innovations being produced, the expenditure profiles of the innovations, and the performance characteristics of the innovations. We also discovered differences among firms and industries in other aspects of the innovation process such as the factors affecting decisions to innovate and problems encountered in innovating. In general these findings were consistent with the different patterns of technological change characterizing the different types of firms and industries. These findings are also reported in the general summary of the report and the specific chapter summaries.

We hope that the numerous findings in the above-noted areas, set out in great detail in the report, will be helpful in the elucidation of a number of the current industrial policy issues facing Canada today. In the balance of this chapter we offer some preliminary comments on the relevance of our findings for a number of these issues.

The Importation of Technology into Canadian Industry

If there is a single issue that has played a central role in discussions of industrial policy in Canada, it is the question of the impact of foreign-controlled firms on our industrial structure and performance. The findings in the report are relevant to a number of important aspects of this broad issue.

There has been great concern in Canada over the relatively low research and development spending intensities of Canadian industries in general when compared to other industrialized countries. This is often traced to the high degree of foreign control of Canadian industry and the nature and performance of foreign-controlled firms. In the background is the view that these firms are technologically underdeveloped because they rely heavily on the technologies of their parents. There is an equally strong contrary view to the effect that these firms benefit from access to the leading-edge technology of parent firms and that Canadian industries are stronger as a result. Our report has raised a number of important considerations relevant to assessing these issues.

From a public policy viewpoint it is not R&D spending in Canada as such which we seek to stimulate as an aspect of our industrial policies, but rather innovation and technological advance. In our view, it is the firms themselves which are in the best position to judge whether the most effective route to achieving desired major innovations is to generate the needed technology internally or obtain it from outside sources in specific cases. It is for this reason we have placed such great stress on distinguishing the source of the technology from its application in the development of major innovations. In our view, evidence that firms are both generating technologies in-house and applying technologies from a variety of external sources is, in general, a sign of a healthy and progressive industry. Some leading-edge world technologies are clearly too complex and costly for Canadian firms to generate solely internally, but they can be effectively applied in Canadian industries. Other technologies may not only be too costly but also inappropriate, given the markets available to firms in Canada. There are clearly two extremes in respect of the utilization of technologies -- complete reliance on imported technology, and complete reliance on internally generated technology. The two extremes seem equally unattractive from a dynamic viewpoint.

Our basic finding in respect of the utilization of technology from external sources is that 24 per cent of all reported product innovations employed only imported technology as their prime technology source. For process innovations, the figure was a little higher, at 35 per cent. In addition, some innovations drew to important degrees both on imported technology and technology developed in-house -- particularly in respect of process innovations. As a result, 26 per cent of the reported product innovations were based in whole or in part on imported technologies and 52 per cent of the process innovations were based in whole or in part on imported technologies. Looked at from the other side of the coin, 66 per cent of all reported innovations were based on technology developed in-house and a further 7 per cent were based on a combination of imported technology and technology developed in-house. Thus in the five industries we analysed, imported technology does not appear to be as significant as is often claimed, and the utilization of imported technologies is heavily biased in the direction of process technologies, though there is great inter-industry variation. None of the industries studied was a consumer products industry where reliance on imported product technologies is likely higher.

Foreign-controlled firms more often utilize imported technologies than do Canadian-controlled firms. For example, 8 per cent of the product innovations and 24 per cent of the process innovations of Canadian-controlled firms had imported technology as their sole primary source as compared to 38 and 40 per cent, respectively, for foreign-controlled firms. Combinations of imported technologies and technologies developed in-house were utilized by both Canadian- and foreign-controlled firms only to a minor extent, in most cases also for process innovations. However, these tended to represent very large innovations. Canadian-controlled firms utilized in-house technology exclusively for 88 per cent of their product innovations and 60 per cent of their process innovations. Nevertheless, over half of the innovations of foreign-controlled firms were based on technologies they developed in-house (61 per cent of their product innovations and 42 per cent of their process innovations). Thus the overall evidence does not reveal a highly unbalanced situation in respect of the importation of technology. Canadian- and foreign-controlled firms are utilizing both technologies developed in-house and imported technologies, and when firms go outside for technologies, it tends more often to be for the complex and costly process technologies. Thus there is clear evidence to this point that firms are making rational economic decisions as to the sourcing of technologies for their major innovations.

Also relevant to the analysis of the importation of technology is the question of the specific sources of the technologies acquired externally by the innovating firms. This is discussed at great length in the report. The dominant external source of technology for the reporting firms is the multinational enterprise. Over half of the technology transfers isolated were intracorporate MNE transfers. Other external sources of technologies to Canadian- and foreign-controlled firms were not being utilized to a great degree. There were some very significant arm's-length technology transfers, but these were few and far between. The foreign-controlled firms clearly have a source of technology which is an important and effective one (a parent or affiliate abroad), but only one Canadian-controlled firm reported a technology transfer from a foreign affiliate.

The low rate of utilization of arm's-length external technology sources raises the concern that for one reason or another the range of effective options open to Canadian firms as to potential external technology sources is neither varied nor rich outside the MNE context. For example, only 14 major innovations utilized external technology sources within Canada (mostly consulting firms) and only 29 innovations drew upon arm's-length technology sources abroad.

Thus in terms of sources of technology, our concern is not so much with the measured degree of utilization of imported technology as with the apparent lack of rich sources of external technology other than the MNE, particularly, of course, in respect of Canadian-controlled firms which in most cases do not have access to technology pools of affiliated firms abroad. One finding we should stress at this point is that for 30 per cent of the innovations of foreign-controlled firms utilizing imported technologies, the technology source drawn upon was an arm's-length source. In other words, the foreign-controlled firms do go outside the MNE when they are of the view that the most cost-effective technology source is not a parent or affiliated firm. Again, this is evidence that normal economic factors are influencing the decisions of these firms as to the utilization of technology sources.

Other characteristics of the reported innovations are also relevant to this broad issue. In terms of origin of control, 59 per cent of the innovations of Canadian-controlled firms were originals and 41 per cent were imitations, as compared to 52 and 48 per cent, respectively, for foreign-controlled firms. Thus foreign-controlled firms have a tendency to more often produce imitative innovations. However, imitative innovations are clearly an important part of the innovation process for Canadian firms of all types and in all industries. Equally, if not more, relevant is the fact that more than half of the imitative innovations were based on technologies the primary source of which was in-house R&D. In other words, firms were copying important innovations introduced abroad using their own in-house technological expertise in the majority of such cases. Furthermore, 22 per cent of the original innovations were based on imported technologies. Canadian-controlled firms more often imitate major innovations introduced abroad via in-house R&D than do the foreign-controlled firms who have access to the technologies of innovations introduced by affiliated firms abroad. Thus 71 per cent of the imitations of Canadian-controlled firms were based on technologies developed in-house as compared to 40 per cent for the innovations of foreign-controlled firms. On the other hand, 31 per cent of the original innovations of the foreign-controlled firms were based in whole or in part on imported technologies as compared to 11 per cent for the Canadian-controlled firms. These data reinforce the dangers inherent in confusing technology and its sources with the nature of the innovations resulting from the application of the technology. It also demonstrates the flexibility, from a technological viewpoint, of the firms actively innovating in the five Canadian industries.

We have presented information in the report concerning the nature and content of the technology transfers to firms in the five Canadian industries. Innovations utilizing imported technology exclusively generally have lower R&D components than those developed in-house, particularly in respect of process innovations. This result is primarily due to the low research component of these innovations, as should be expected. In fact, the development components of the two types of innovations are very similar. Those innovations employing both in-house and imported technologies, on the other hand, have higher research and higher development components than innovations based on in-house technology alone. The data indicate that even when the innovations have imported technology as their primary source, considerable amounts of research and development expenditures are made by the innovating firms in the course of applying the technology, particularly in the case of product innovations.

The expenditure profiles on innovations can also be isolated for foreign- and Canadian-controlled firms by source of technology. It is the process innovations of the foreign-controlled firms based solely on imported technologies which stand out in such comparisons. These innovations, on average, required very little R&D spending in Canada in the course of being introduced into the operations of the Canadian subsidiaries. For all other classes of innovations based in whole or in part upon imported technology, considerable R&D spending was undertaken by the innovating firm in producing the desired innovations. Whether the technology for innovations utilizing imported technologies would or could have been developed in the Canadian firms is an open question. In our interviews, many of the firms did not believe they could duplicate the technology being imported, at least at a cost which would make it worthwhile to proceed with the innovation in question. In any case, the general view that it is hardware which is being transferred to the foreign-controlled firms and not technology, is not strongly supported by these data in the majority of cases i.e. there is evidence of a real transfer of the technology and not simply a reliance on technologies developed elsewhere.

The final issue in respect of the importation of the technology relates to the terms and conditions attached to the technology transfers. We found that in about 42 per cent of the transfer agreements there were restrictions on the territory of manufacture of the products based on the technology, and that in about 35 per cent of the transfers there were some restrictions on the territory of sales of the products. In about 75 per cent of these latter cases, the transfers restricted sales solely to Canada. These restrictions were generally a little more common in the transfer agreements of foreign-controlled firms (and particularly in the intracorporate MNE agreements). Where such restrictions are found, the frequency of restriction on selling abroad at all was very much greater for the foreign-controlled firms' agreements, as would be expected since the MNE's have a presence in so many countries.

Although the frequency of restrictions in the transfer agreements of both foreign- and Canadian-controlled firms is by no means insubstantial, it is not as great as might have been expected (e.g., 35 per cent of the transfer agreements territorially restrict sales and only 26 per cent restrict sales solely to Canada - i.e., prohibit all exportation). Nevertheless, other information in our report gives rather a different picture. Our independently constructed export performance indicators for product innovations shows very poor export performance in respect of innovations based on imported technologies. Even in the absence of widespread explicit agreements, the export performance for the majority of the product innovations based on imported technology has not been good. This should come as no great surprise -- many, though certainly not all, of these agreements are directed to copying innovations already on the market abroad, and thus penetration of export markets would be difficult in many such cases. These innovations would be playing much more of an import-replacement role in Canada.

A further performance issue should also be highlighted -- innovations based on imported technologies less often lead to further R&D and innovation (spin-offs) than is the case for innovations based on technologies developed in-house. Again, one should not be unduly surprised at this result, but the difference in performance is clear (though not as marked as the export performance indicators effects).

Finally, the issue of restricting technology recipients as to sources of inputs to be used in conjunction with the imported technologies does not show up in our study to be an important one. Formal restrictions are almost non-existent. No doubt, technological imperatives dictate the use of specific components in conjunction with specific technologies, but this is a different issue on which we have no direct information. On the other hand, in the examination of major problems firms experience in innovating, difficulties in obtaining needed components for major innovations show up as a problem.

In summary, the report contains considerable evidence that firms in the five industries examined are taking advantage of their comparative advantages in the innovation and technological change processes, developing technologies internally and drawing on outside sources of technology in appropriate cases. We do not pretend to be able to determine what an optimal mix of types of innovations or degrees of utilization of imported technologies should be, but we find little evidence of a very unbalanced situation. Given our findings for the performance indicators on imported technology, had we found an unbalanced reliance on imported technologies it would have been a cause for concern. Performance in specific industries in the different areas discussed here generally varied considerably, as set out at some length in the report. The main concern our findings raise in respect of the many aspects examined, is with the apparent scarcity of external sources of technology for major innovations in Canada, and the scarcity of such resources in general outside of the intracorporate MNE sources.

The Direction of Technological Change in Canadian Industries

An important issue discussed in the report relates to the direction of technological change over time in the five industries studied. We have noted some evidence of deterioration in these processes over time, particularly in the latter half of the 1970s. For example, there has been a slight tendency in most of the five industries to concentrate more on improvement innovations, and, in general, the proportion of innovations with shorter pay-back periods increased noticeably in the latter half of the 70's. In addition, total spending per innovation in current dollars has not increased in the 1970s as would have been expected, if only because of the rising costs of innovating, and in fact for most classes of innovations spending per innovation was either flat or actually decreased in the 1970s as compared to the 1960s. The decline would have been more marked if spending had been expressed in constant dollars. Given the nature of these indicators, we have tended to ascribe the deterioration in the innovation process in the latter half of the 1970s particularly, to macro-economic factors, i.e., to the unsatisfactory performance of the economy in the 1970s in terms of output, price stability, trade, and investment, and the uncertainties generated by this poor macro-economic performance.

However, in other basic areas there are signs pointing in the other direction. There have been no significant changes in the proportions of major innovations which are original and those which are imitations in the 1970's. On the other hand, imitations have increasingly tended to be developed via the generation of in-house technologies. Furthermore, the proportion of innovations based on imported technologies has, in fact, declined over time.* Both these latter considerations appear to point in the direction of the development of a strengthening technological base for Canadian industries over time. In respect of the decline in the proportion of innovations based on imported technologies, this may well reflect the increasing technological sophistication of Canadian firms and the growth of the Canadian market itself over time, which in the absence of strong

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* In the 1970s only about 20 per cent of reported innovations had imported technology as their sole primary source.

technological trends to the contrary, expands the number and type of innovations which can be introduced into Canadian industries on an economically sound basis. In any event, the weight of the evidence in the report indicates that, if anything, the technological bases of the Canadian industries examined are becoming stronger.

The evidence of a growing ability to develop and utilize technologies in-house is present both for Canadian- and foreign-controlled firms. The view that the foreign-controlled firms simply draw on technology of parent and affiliated firms abroad and have no independent technological capabilities was not confirmed in the report. There is clearly a great deal of R&D strength in the foreign-controlled firms, and these strengths appear to be increasing over time. In the 1970s only one-third of their innovations had imported technology as their primary source as compared to one-half in the 1960s. These data suggest that an evolutionary process is characterizing the behaviour of the foreign-controlled firms.

We tried to obtain a better fix on this issue in our interviews. In many cases, the development of the foreign-controlled firms with respect to their technological expertise and activities followed a fairly common pattern in the three product-oriented industries. Many of these firms were set up in Canada essentially as import houses. Over time the firms found it difficult to penetrate the Canadian market to a significant degree, because they were weak in terms of the technological expertise which comes only as a result of producing the products. The firms found it difficult, therefore, to sell and/or service products. An additional pressure to manufacture was the desire to alter their products to fit distinctive Canadian conditions and standards. The outcome was that these subsidiaries were given some sort of manufacturing presence in Canada (production of a specific product or component). The pattern thereafter was for these firms to expand their manufacturing activities, their adaptive R&D activities, and over time they began to produce products which were unique to the MNE. In a number of such cases the Canadian subsidiary was able to convince its parent of the competitive merit of the new product and of its ability to produce it efficiently in Canada. The subsidiary would then gain access to the world-wide marketing facilities of the parent firm. The situation in respect of the two process-oriented industries, based on Canadian natural resources is, of course, quite different.

That such an evolutionary process in the foreign-controlled firms has been taking place is confirmed by the data. Almost half of all innovations of foreign-controlled firms are originals and more than half of their product innovations are originals. Utilization of imported technologies in the development of their major innovations is tending to decline over time. This movement towards technological maturity is, no doubt, rather similar to the general evolution of the small firm over time, but in the case of the Canadian subsidiary it is assisted by access to the strong technological bases of the parent firms. Even in respect of innovations based on imported technologies, considerable amounts of R&D work are undertaken in the Canadian subsidiary in many cases. The view that these firms are not benefitting from transfers of technology and that the normal learning processes are not coming into play as the subsidiaries gained experience with the introduction of new technologies into their operations was always, in our view, a rather dubious one.

Governments in Canada very recently have evinced great interest in the concept of a "world product mandate" for Canadian subsidiaries. A world product mandate refers to a situation where the Canadian subsidiary has primary responsibility for the production, development and improvement of a specific product (or component). The outcome of the evolutionary process discussed above, is, in a sense, a world product mandate which the Canadian firm has earned as a result of its innovative activities. However, there are two aspects of this scenario which should be stressed. The innovation was developed in Canada and the Canadian subsidiary was able to convince the parent firm that the innovation could be produced in Canada, at least as cost-effectively as at other production sites available to the MNE. This does not imply that all production would take place in Canada. Viewed in this way, the development of the world product mandate is very close to the normal rationalization process engaged in by the MNE.

Governments might be able to design policies which would encourage or strengthen this evolutionary process. For example, they might design their policies, say, procurement policies, in a way which would encourage foreign-controlled firms in Canada with little or no manufacturing presence, to obtain such a presence. As mentioned above, there are pressures within the small firms in that direction in any event. Governments might also be able to design policies which would expedite the growth and development of sales of innovative products developed by these firms as a means of strengthening of their hands in convincing parent firms of the value of their innovations. Procurement policies directed to this end would imply quite a bit of knowledge and expertise on the part of governments. Assuming such policies could be made effective they would, of course, be equally applicable in respect of the innovative developments of all small and medium-sized Canadian firms, regardless of origin of control.

The view that there is a wide range of products which could somehow be turned into world product mandates is a mistaken one -- clearly the sorts of conditions necessary for the successful development of world product mandates are narrowly circumscribed and cannot be artificially created. A good example of this is the situation which a few foreign-controlled firms with European parents brought to our attention. In a number of cases these firms approached their parent with proposals that they be granted a "world product mandate" in a particular important line of products. The parent firm studied the proposals and concluded that it would be much more efficient if their subsidiary in the large United States market were given the mandate, based on production and marketing cost considerations. On the other hand, one of these Canadian subsidiaries had obtained a world product mandate based on a unique product they originally developed for the Canadian market.

Issues in Respect of the Small Firm

To this point we have concentrated to a large extent on the implications of the origin of control of Canadian firms, owing to the many industrial policy issues relating to the utilization of imported technology by firms in Canadian industries. However, the report also isolates some significant differences between large and small firms in respect of innovation and technological change processes. In addition, it becomes clear in reviewing the general findings in the report that the differences between small and large firms are often the basis for many, though not all, of the differences between Canadian- and foreign-controlled firms discussed in the report. This is of course, a generalization - there are some large and technologically sophisticated Canadian controlled firms in all the industries examined. In any event, the following discussion serves to further elucidate both issues.

Small firms are more product-oriented than large firms. Most of the major process innovations reported were extremely costly and far beyond the reach of the resources of the small firm. In addition, small firms less often cited technical difficulties as a major problem in developing their innovations than did larger firms. On the other hand, they more often found marketing and financial problems to be serious problems affecting the development of their major innovations. The motivation of small firms in introducing their innovations was more often to fill market gaps as compared to the larger firms seeking to expand their markets. These findings are consonant with the recent developments in the theory of the nature and role of the small firm. Small firms often enter high-technology industries with a view to producing a specific type of technically sophisticated product. The founders of such firms have a great deal of technical expertise, but the growth of the firm causes problems because of a lack of expertise on the financial and marketing side. An important set of policies which would assist small firms would thus be management related.

Examples of such problems can be found on the financial side. It is small and large firms which fund large proportions of their innovations wholly from internal sources. Unlike large firms which in general, have had little difficulty financing their major innovations, reliance on internally generated funds by small firms appears to reflect difficulties in obtaining funds externally. When small firms are able to obtain funds for their major innovations externally, we find they tend to rely on large numbers of sources, obtaining only small proportions of the required funding from the various sources, and they still fund large proportions of these innovations from internal funds. The government is an important source of external funds for part of the funding of the innovations of small firms which were funded externally. Most of these tendencies are more marked for small Canadian-controlled firms than for small foreign-controlled firms. Nevertheless, many small firms stressed in our interviews that they lacked the resources necessary to do the planning and financial analysis required by governments which would allow them to take full advantage of government funding programs.

Differences between small Canadian- and small foreign-controlled firms primarily appear to stem from the fact that the small foreign-controlled firms have access to parent and affiliated firms in a variety of areas -- e.g., as a source of technology, a source of ideas for innovations, a source of marketing expertise, a source of funding, etc. This same consideration applies more generally in respect of differences between foreign- and Canadian-controlled firms. Weaknesses in respect of process innovations on the part of Canadian-controlled firms are evident in the report and these no doubt relate in part to size considerations and to technology-source considerations. We have already expressed concern over the apparent lack of arm's-length sources of technology for Canadian firms. This concern is strongest, of course, in relation to the domestically-controlled firms. That the parent and affiliated firms of Canadian subsidiaries are a powerful source of advanced technology suitable for application in the innovation process should come as no surprise. Parent and affiliated firms are in most cases larger than the Canadian firms;

they are involved in the production of similar and usually broader lines of products; and they operate in a number of countries.* The question is, could such sources of technology be developed in Canada of a world standard quality?

Reliance on technology sources within Canada by firms in the five industries in respect of their major innovations was found to be almost non-existent. There is significant basic research underway in Canada in universities and basic research institutes, but it may be that the technology generated in these institutions is not suitable for application in the Canadian industries examined in this report. It is really fundamental research (long-run applied research) rather than basic research centres which would represent a fertile external source of technology for Canadian firms. The concept of co-operative generic research centres recently put forward in discussions of industrial policies would seem to be of this type. Clearly Canada cannot rival the MNE as a source of leading-edge technologies across the board. The generic technologies chosen to form the basis of such centres would have to be carefully selected on the basis of a broad range of realistic economic and technical criteria. Such centres, whether attached to universities or other research institues, would have to have their primary input from firms in private industry. One additional benefit of such centres would be to make available to firms, particularly small firms, sophisticated facilities for testing of innovations. Such centres could become a source of state-of-the-art technology for Canadian firms which, to date, have not found fertile sources of technologies outside the MNE. In light of our remarks above in respect of world product mandates, foreign-controlled firms should clearly also be encouraged to participate in the development and utilization of such centres.

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* For example, Canadian subsidiaries of European firms in some industries, e.g., telecommunications equipment and components, often look to the United States subsidiaries of the parent for technological expertise and information, rather than to the parent, because the technologies in North America are more advanced than those available in Europe and more "practical" -- i.e., easier to apply.

Conclusions

We have stressed the preliminary nature of this report in terms of the findings presented and their analysis and interpretation. At this point in time, the main purpose of the report is to present the findings of the survey in a complete enough manner to elicit comments and advice on the form, analysis, and interpretation of the data presented. The numerous findings in the report on a wide range of subjects are obviously interrelated in ways which have not been sufficiently drawn out in the preliminary report. This concluding chapter is most tentative and preliminary and was designed more to elicit comments and reactions than to represent a serious attempt to fully summarize the implications of the findings in the report for the numerous relevant industrial policy issues. We believe the information presented and analysed in the report can play an important role in helping us to analyse and assess the many industrial policy issues facing Canada in the 1980s. It is not our intention, even in the final report, to make explicit industrial policy recommendations. This report is part of a broader program of basic research underway at the Council, designed to form the basis of an Economic Council of Canada document on Canadian industrial policies.

In viewing the many findings of the report as a whole in respect of the innovation and technological change processes in the five industries, we were most impressed with the extensive evidence that firms were pursuing their comparative advantages within the Canadian industrial framework. We found that all types of firms and industries analysed were utilizing domestically-generated technologies to develop some innovations, importing technologies to develop other innovations, and employing combinations of internally-generated and externally-acquired technologies in still other cases. We found all firms were developing both new products and processes and improving on their existing ones. Firms were producing original innovations and imitating important innovations being introduced abroad. Firms were imitating innovations via the utilization of imported technologies and technologies developed in-house, and were also producing original innovations based on both internally developed and externally acquired technologies.

There were differences in degree in almost all these aspects for firms and industries with different characteristics, but it appears to us that there were sound economic factors in play capable of explaining many of these differences. For one example, foreign-controlled firms more often utilized imported technologies because they had available to them a rich external technology source -- the parent firm; but even so, the foreign-controlled firms also obtained technologies from arm's-length sources in particular cases. Utilization of imported technologies by all firms was more common in the case of process technologies. Small firms, on the other hand, specialized in product innovations. The evidence of diversity and flexibility in respect of innovation and technological change in the industries examined on the part of all the firms suggests a high degree of technological sophistication. If we had one concern, it related not to the degree of reliance on imported technologies in the industries examined, but rather to the apparent lack of arm's-length technology sources available to Canadian firms. Finally, we were impressed with the evidence of a strengthening in the technological bases of the five industries over time.

Appendix I

THE SURVEY QUESTIONNAIRE AND INDUSTRY RESPONSE RATES

The Survey Questionnaire: Content and Types of Innovations Reported

The purpose of the survey questionnaire was to acquire information related to the process of innovation and technological change in Canadian firms. The five industries selected for analysis include a wide range of types of industries, i.e., product and process oriented industries consisting of both large and small and Canadian- and foreign-controlled firms, and industries involved in extractive and primary and secondary manufacturing activities. No consumer product industries were included. The industries are telecommunications equipment and components, electrical industrial equipment, plastics compounds and synthetic resins, non-ferrous smelting and refining, and crude petroleum exploration and production. The survey questionnaire* was sent to all firms that could be identified as being active in these industries in 1978.

Firms were asked to identify and describe major innovations (up to three) which they had introduced over the 1960-1978 period.** Major innovations were defined as major new or improved products or production processes which contributed most to the firm's profitability (many firms quite properly interpreted this to mean contributions to the long run profitability of the firm, rather than using a strict short run profitability criterion). Firms were encouraged to report major innovations regardless of the source of the technology for the innovation.

* A set of three questionnaires (one per innovation) was sent to each firm in the five industries being surveyed in mid-November, 1979. Firms which had not responded by the first week in January, 1980 were then sent a follow-up package containing a single questionnaire. Firms which had not responded by early February, 1980, were telephoned to obtain some information on the reasons why the firm had not responded.

** However, firms reported 23 innovations introduced in 1979 and 5 in early 1980.

Information was sought on a wide range of elements in the innovation process. A copy of the basic questionnaire is presented at the end of this appendix. Questionnaires sent to firms in each industry were identical, with the exception of references to specific industry names.

Innovations reported by firms in the telecommunications equipment and components industry had applications in the telephone, radio, CATV and satellite fields. Some examples of the reported innovations are electronic PABXs; digital multiplex systems; automatic number identification equipment; high voltage underground microwave systems; mobile radio telephones; CATV cable, antennas, and amplifiers; earth stations; and devices to receive microwave signals and amplify them for transmission to satellites. The telecommunications equipment and components industry is ill-defined from a statistical point of view; for example, the industry is only now being given a unique identifier in the Standard Industrial Classification of Statistics Canada. Firms active in this industry cut across a number of traditional industry boundaries, including firms in the computer, cable, communications, and business equipment industries. This variety also is evident in the type of innovations reported, such that in addition to the innovations listed above, innovations in coaxial cable, fibre optics technology, computer-aided design, and computerized supervisory and data acquisition systems were also reported upon by firms. Many of the innovations were oriented towards a reduction in the number of components in products or systems to reduce their size and increase their efficiency.

Innovations reported upon by firms in the electrical industrial equipment industry include improvements to many traditional products such as low and high voltage transformers, gas turbines, shunt reactors, relays, safety switches and air circuit-breakers. Other examples are transportable generating units, centres for the remote control of motors, and mosaic tile graphic display boards. The use of computer technology is in evidence in this industry as well as in the telecommunications equipment industry, as is illustrated by reports on the use of robotics, numerically controlled machinery and computer-aided design. Again, great emphasis is placed upon the development of lighter, more energy-efficient equipment which is able to withstand extreme conditions. There are many instances of replacement of electro-mechanical by electronic components and of the use of solid state devices and integrated circuits,in conjunction with more self-monitoring systems for example.

Firms in the plastics compounds and synthetic resins industries reported upon the development or improvement of various copolymers, polyethylene and PVC resins to give only a few examples. The emphasis is upon new resin and compound properties such as the development of thermoplastic rubber sufficiently strong to replace metal for some applications; special thickeners for latex compounds; textile resins to give permanent press properties; and special bonding resins and foams for use in insulation and pulp and paper products, for example, waferboard resins to make possible the use of low-value wood. Equipment innovations such as improved calendars capable of producing wider, thicker films were also reported. Attention is given to not only the imparting of new properties to resins and compounds, but also to their production at lower temperatures with shorter time cycles, i.e., to lower energy consumption in general.

Innovations reported upon by the non-ferrous smelting and refining firms relate to a number of metals including lead, nickel, zinc, copper, ilmenite, uranium, aluminum, gold and silver. Some examples of the reported innovations are an oxygen-softening process for lead; improved desulphurization of copper-nickel concentrates; electric furnace matte smelting of nickel sulphide concentrates; a zinc hydrometallurgical process; electric furnace smelting of ilmenite; vacuum casting of uranium metal using a furnace capable of melting the ingots as produced rather than having to cut them into small pieces; simultaneous casting of aluminum billets; and improved secondary recovery techniques applied to gold and silver. Great importance is placed upon the reduction of processing costs, for example, through the development of bath additives to lower melting points, and upon the reduction of emissions of by-products such as sulphur and arsenic. Equipment innovations were also reported. Two examples are the use of wheel-breakers in aluminum smelters to break the crust of the electrolyte and the use of rubber lining in autogenous grinding mills.

Firms in the crude petroleum production industry reported upon innovations involving exploration, development and production. Examples relate primarily to offshore production, heavy oil, and oil sands. At the exploration stage, significant developments in seismic techniques such as the use of vibration rather than dynamite for seismic wave input to identify oil and gas deposits; the use of heliportable seismic operations to replace trucks; and major advances in using interactive computer interpretation techniques and use of digital rather than analogue techniques were reported. The development of ice-platform drilling techniques for crude petroleum production is an example of one of the offshore production innovations reported. There were also several cases reported of the application of enhanced recovery techniques such as miscible flooding, steam stimulation, water flooding, and wet combustion. Innovations were also reported relating to de-sanding systems, shortening of well completion times, new well-logging techniques and processes to remove hydrogen sulphide from sour crude. In many cases of innovations reported upon by crude petroleum producers, the innovation was system-wide and involved the application of several modified techniques in new sequences and combinations. This type of large-scale technological change is best illustrated in the case of oil sands projects in Western Canada where new equipment and extractive and upgrading techniques have been developed to meet unique scale and material handling requirements.

Response Rates

Turning now to the response to the survey, of the 410 firms contacted, 170 returned one or more of the questionnaires, for an overall response rate of 41 per cent. Response rates by industry, are given in Table 1. An additional 8 firms (2 per cent of the total population), while not completing questionnaires, did return letters describing their R&D efforts and the process of innovation within their firms in some detail.

Table 1

RESPONSE RATE TO INNOVATION SURVEY

Industry	Total Number of Firms In Industry	Number of Firms Returning One or More Questionnaires	Response Rate (%)
Telecommunications Equipment and Components	119	67	56
Electrical Industrial Equipment	128	52	41
Plastics Compounds and Synthetic Resins	38	21	55
Smelting and Refining	30	14	47
Crude Petroleum Production	95	16	17
All Industries	410	170	41

The relatively high response rate at the firm level was matched by a high degree of co-operation on the part of the respondents in completing more than one questionnaire when they felt it relevant to do so. Overall, the 170 respondents returned a total of 291 questionnaires, each reporting on a single innovation. The total number of completed questionnaires returned by industry is given in Table 2.

Table 2

NUMBER OF REPORTED INNOVATIONS

Industry	Number of Firms Which Returned Questionnaires	Number of Firms Returning the Indicated No. of Questionnaires						Total Number of Questionnaires Received (i.e. Innovations Reported)	Number of Questionnaires Per Responding Firm
		1	2	3	4	5	6		
Telecommunications Equipment and Components	67	39	13	13	0	1	1	115	1.7
Electrical Industrial Equipment	52	40	5	7	0	0	0	71	1.4
Plastics Compounds and Synthetic Resins	21	9	4	8	0	0	0	41	2.0
Smelting and Refining	14	4	3	6	0	1	0	33	2.4
Crude Petroleum Production	16	7	4	4	1	0	0	31	1.9
All Industries	170	99	29	38	1	2	1	291	1.7

Of the 291 questionnaires, 283 (from 169 firms) were found to be useful for purposes of analysis. An industry breakdown is given in Table 3 below.

Table 3

NUMBER OF QUESTIONNAIRES USEFUL FOR ANALYSIS, BY INDUSTRY

Industry	Number of Questionnaires (Innovations)	Number of Firms
Telecommunications Equipment and Components	108	65
Electrical Industrial Equipment	68	50
Plastics Compounds and Synthetic Resins	40	21
Smelting and Refining	33	14
Crude Petroleum Production	30	16
Other*	4	3
All Industries	283	169

*Four innovations from 3 firms are included in the overall analysis but not in the individual industry analysis for the following reason. Although firms were asked for information on those innovations which had most contributed to their profitability in the fields of specialization of the surveys (telecommunications equipment, plastics compounds and synthetic resins, etc.), 3 firms reported on four innovations which were in related but different fields and thus were not coded to one of the 5 industries.

Fifty-three firms (13 per cent of the total population) wrote letters saying that they had not introduced any major product or process innovations during the 1960 to 1973 period. An industry breakdown of such firms is given in Table 4.

Table 4

NUMBER OF FIRMS WHICH INTRODUCED NO MAJOR INNOVATIONS DURING THE 1960-78 PERIOD, BY INDUSTRY

Industry	Total Number of Firms In Industry	Firms Introducing No Major Innovations No.	%
Telecommunications Equipment and Components	119	7	6
Electrical Industrial Equipment	129	12	9
Plastics Compounds and Synthetic Resins	38	5	13
Smelting and Refining	30	3	10
Crude Petroleum Production	95	26	27
All Industries	410	53	13

ECONOMIC COUNCIL OF CANADA
DEPARTMENT OF INDUSTRY, TRADE AND COMMERCE

INNOVATION IN THE TELECOMMUNICATIONS EQUIPMENT (AND COMPONENTS) INDUSTRY

This is part of a study of innovations — major new/improved products and production processes — and of the ability of Canadian firms to generate, rapidly adopt, and commercialize them. *We are interested in those innovations,* ***created by your firm or adopted from elsewhere*** *during the 1960-1978 period, which have most contributed to your firm's profitability in the telecommunications equipment and components field.* We have included three copies of this questionnaire for descriptions of up to three innovations.

1. Please name and briefly describe this innovation. ______________________________

____

____

____

2. What is unique or different about this innovation? ______________________________

____

____

3. Which *one* of the following best describes this innovation?
   - ☐ a new product requiring development of a new production process,
   - ☐ a new product using an existing or slightly modified production process,
   - ☐ an improved product requiring development of a new production process,
   - ☐ an improved product utilizing modifications to an existing production process,
   - ☐ a new production process for existing products,
   - ☐ an improved production process for existing or improved products.

4. What was the year of your firm's first commercial launch (products) or first use (processes) of this innovation?

   ____

5. Was *this or a very similar innovation* first commercialized or used prior to the above date?

   ☐ Yes, ☐ No. If yes, please indicate, to your knowledge, the approximate year and the country of the first world launch or use of the innovation. ____________ (year) ______________________________ (country)

6. Please estimate how many months elapsed from your first significant employment of human or capital resources on this innovation to its first commercial launch or first use. ____________

7. What was the primary source of the technology for this innovation?
   - ☐ (a) arrangement or agreement with a source outside your firm,
   - ☐ (b) research and developmental work within your firm.

8. If the primary source of the technology was (a) above, was it obtained
   - ☐ from your parent,
   - ☐ from another affiliate or subsidiary of your parent,
   - ☐ from one of your subsidiaries or affiliates (if you are the parent),
   - ☐ by license or purchase from a customer,
   - ☐ by license or purchase from a supplier,
   - ☐ by joint venture with an unaffiliated firm,
   - ☐ other (please specify) ______________________________

   Was the primary source of the technology non-domestic? ☐ No, ☐ Yes. If yes, please name the source country.

   ____

9. What were the main sources of ideas and information most useful in the generation and development of this innovation? (Please *check* appropriate boxes in the list below)

☐ suppliers,	☐ trade journals,	☐ your R&D group or equivalent,
☐ customers,	☐ trade fair or trade association,	☐ your management,
☐ competitor firms,	☐ independent inventor,	☐ your sales force,
☐ subsidiary or affiliated firm,	☐ gov't research institution,	☐ your marketing personnel,
☐ parent firm,	☐ universities,	☐ your production personnel,
☐ consultants,	☐ publications other than trade journals,	☐ other (please specify) ____________

10. Is this innovation patented in Canada? ☐ No, ☐ Yes. If a process, are the products flowing from the process patented in Canada? ☐ No, ☐ Yes. Name of owner of Canadian patent ______________

11. Did obtaining the technology for this innovation involve a licensing, or other (written or unwritten) transfer agreement? ☐ No, ☐ Yes a license, ☐ Yes other transfer agreement (If no, please go to #14);

Is this agreement:	*No*	*Yes*
(a) part of a continuous transfer, including access to future technology developed by the other party?	☐	☐
(b) a one-time transfer of technology for a specific product or process?	☐	☐
(c) a cross-licensing agreement?	☐	☐
(d) and is the agreement in writing?	☐	☐
and does it specify the right to manufacture?	☐	☐
the right to sell?	☐	☐
the right to use in manufacture?	☐	☐
the right to use of a trademark or name?	☐	☐

Year agreement entered ______________

12. Do any of these licensing or transfer agreements (written or unwritten) specify the territory in which you may manufacture or sell the products or processes resulting from the technology?

☐ No, ☐ Yes;

and do the agreements give the *exclusive* right to manufacture? ☐ No, ☐ Yes;

the *exclusive* right to sell? ☐ No, ☐ Yes;

territory specified in manufacture ______________

territory specified in sales ______________

or specify that the other party shall own rights to improvements made to the technology?

☐ No, ☐ Yes with your firm, ☐ Yes exclusively;

or specify sources from which any inputs must be purchased? ☐ No, ☐ Yes.

13. Please estimate the total royalties and/or other payments made for the technology for this innovation through to the end of 1978. $______________

14. Do *you* license or sell any technology related to this innovation to other companies? ☐ No, ☐ Yes. If yes, please estimate the total royalties and/or other payments received for the technology through to the end of 1978. $______________

15. Please *estimate*, for this innovation, the approximate costs to the firm of the stages of the process set out below (enter "0" where no expense was incurred).

Stages of Innovation Process	*Cost Estimates for this Innovation*
Basic research	$ ______________
Applied research	$ ______________
Development (e.g., engineering, layout, design, prototype construction, pilot plant construction, testing, market evaluations, etc.)	$ ______________
Manufacturing start-up (e.g., tooling, plant arrangement, construction of additional plant, acquisition of equipment, etc.)	$ ______________
Marketing start-up	$ ______________
Total cost	$ ______________

16. Please estimate what percentage of the funds for the development of this innovation through to your first commercial launch or first use were obtained from these sources:

Internal	______________ %
Parent or affiliated firm	______________ %
Private investors (as opposed to financial institutions)	______________ %
Bond issue	______________ %
Bank financing:	
— conventional bank loan	______________ %
— income debenture and/or floating rate preferred	______________ %
Venture capital firm	______________ %
Government	______________ %
Other (please specify) ______________	______________ %

If you cited government, please list the name of the program(s) under which you received funding. ______________

____

17. How long did it take for your firm's expenditures on research and development for this innovation to pay off after first commercial launch or first use?

☐ Less than 3 years ☐ 3-5 years ☐ More than 5 years

18. If this innovation is a product, are you a ☐ producer, ☐ assembler, ☐ seller to user firms, ☐ wholesaler, ☐ retailer, ☐ importer, ☐ exporter, of the product (Multiple answers permitted).

19. Please list the most important classes of customers to whom you sell your product innovation or the products flowing from your process innovation (e.g., particular types of firms or institutions, governments, consumers, etc.)

In Canada ______________________ Abroad ______________________

20. Please estimate the number of firms (whether or not based in Canada) which offer products directly competing in Canada with your product innovation or with the products flowing from your process innovation. __________

21. Please indicate the *three* most important factors in your firm's decision to develop this innovation.

☐ response to foreign competitors employing similar innovations,
☐ response to domestic competitors employing similar innovations,
☐ to take advantage of new technological capabilities,
☐ to reduce labour requirements,
☐ to reduce energy requirements
☐ to reduce capital requirements,
☐ to meet governmental regulatory requirements,
☐ perception of a new market or gap in existing markets,
☐ as a result of pressures from deteriorating profit margins,
☐ to improve quality of the products covered by this innovation,
☐ interactions with your customers,
☐ interactions with your suppliers,
☐ to gain a larger market share,
☐ other (please describe) __________

22. What effect did this innovation have on the number of workers employed by your firm?

Production Workers:	☐ negligible,	☐ net increase,	☐ net decrease
Non-Production Workers:	☐ negligible,	☐ net increase,	☐ net decrease
Total Number of Workers:	☐ negligible,	☐ net increase,	☐ net decrease

23. Were labour force skill requirements raised as a result of this innovation? ☐ No, ☐ Yes. If yes, please indicate how these were met for:

Production Workers: ☐ hired from outside, ☐ re-trained in firm, ☐ sent outside for re-training

Non-Production Workers: ☐ hired from outside, ☐ re-trained in firm, ☐ sent outside for re-training

24. Please briefly describe any important structural or organizational changes in your firm occasioned by this innovation (e.g., increased plant specialization; increased scale of production in plants; introduction of new functions such as wholesaling, retailing, exporting, after-market servicing; introduction of new organizational division; etc.).

25. Please briefly describe your firm's most difficult problem in developing and commercializing this innovation (e.g., difficulty in financing, in obtaining required components, technical problems, lack of marketing facilities, etc.).

26. Did the research or developmental work on this innovation lead to further R&D to produce additional innovations?

☐ No, ☐ Yes. If this work led to the introduction of an additional innovation by your firm, please describe the innovation. __________

Firm Information

Some of the following questions refer both to the year 1978 and the year in which you first commercialized or used the innovation. In completing information for a second and third innovation, you need only re-do that portion of Firm Information on dotted lines and add your firm name for identification purposes.

Name of Firm ____________________

Head Office Address (or, if no head office in Canada, address of principal office in Canada) ____________________

____

Year of Incorporation of Firm __________, Country of Incorporation ____________________

1. Please list the countries outside Canada in which you have the following operations relating to telecommunications equipment and components:

   Sales Offices ____________________

   R&D Units ____________________

   Production Units ____________________

   Assembly Units ____________________

2. Is your firm controlled by another firm? ☐ Yes, ☐ No. If Yes, are you a wholly owned subsidiary? ☐ Yes, ☐ No. Please list the name and country of controlling firm. ____________________ name

   ____________________ country

3. What approximate percentage of your firm's production workers in telecommunications equipment and components are covered by collective bargaining? ______ %

4. Please provide the information requested below, *estimating* where necessary. (Include all your R&D expenditures, no matter how financed.)

	1978	Year of First Commercialization or Use of this Innovation (Question 4, page 1)
Total annual sales of firm ($)	______	....
Percentage exported (%)	______	....
Annual sales telecommunications equipment and components ($)	______	....
Percentage exported (%)	______	....
Annual sales of this product (if a product innovation) ($)*	....	....
Percentage exported (%)	....	....
Annual sales of products flowing from this process (if a process innovation) ($)*	....	....
Total amount spend on R&D by firm ($)	______	....
Amount spent on R&D in telecommunications equipment and components ($)	______	....
Total number of employees of firm	______	....
Number of employees in telecommunications equipment and components	______	....
Number of qualified scientists and engineers engaged in R&D in telecommunications equipment and components	______	....

*Where relevant, please include in your sales figures an estimate of the value of products retained within your firm for further fabrication.

Finally, please indicate the name and telephone number of a person in your firm we might contact for further information about this material, preferably a person who advocated the introduction of this innovation.

____

If you have any questions or wish further forms in order to better represent your firm's innovative capabilities, please call or write Technological Change Group, The Economic Council of Canada, Box 527, Ottawa, Ontario, K1P 5V6, (613) 993-3522.

Please return this form to the above address as soon as convenient, or by December 19, 1979 at the latest.

APPENDIX A

SUPPLEMENTARY TABLES FOR CHAPTER 8

Table A-1

TELECOMMUNICATIONS EQUIPMENT AND COMPONENTS
CONTRIBUTIONS TO TOTAL FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY
BY SOURCE, BY CONTROL, BY SIZE

						Bank					
		Internal	Parent	Private Investors	Bond Issue	Conventional Loan	Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
						$ Million					
Canadian-Controlled Firms											
100 or less employees	(23)*	4.4	0.2	0.3	0	0.2	0	0.1	1.4	0.4	7.0
101-500 employees	(8)	2.5	7.7	0	0	0.3	0	0	2.2	0	12.7
over 500 employees	(2)	1.1	0	0	0	0	0	0	1.1	0	2.2
Total	(33)	8.0	7.9	0.3	0	0.5	0	0.1	4.7	0.4	21.9
Foreign-Controlled Firms											
100 or less employees	(11)	1.5	1.5	0	0	4.5	0	0	2.3	0	9.8
101-500 employees	(10)	2.3	2.1	0	0	0	0	0	0.5	0	4.9
over 500 employees	(3)	6.2	0	0	0	0	0	0	1.6	0	7.8
Total	(24)	10.0	3.6	0	0	4.5	0	0	4.4	0	22.5
Total	(57)	18.0	11.5	0.3	0	5.0	0	0.1	9.1	0.4	44.4

* Brackets contain number of innovations

Table A-2

TELECOMMUNICATIONS EQUIPMENT AND COMPONENTS
PERCENTAGE DISTRIBUTION OF CONTRIBUTIONS TO TOTAL FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY BY SOURCE, BY CONTROL, BY SIZE

						Bank					
		Internal	Parent	Private Investors	Bond Issue	Conventional Loan	Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
						-- (%) --					
Canadian-Controlled Firms											
100 or less employees	(23)*	62.7	2.9	4.3	0	2.7	0	1.0	20.8	5.6	100.0
101-500 employees	(8)	19.8	60.5	0	0	2.5	0	0	17.2	0	100.0
over 500 employees	(2)	50.0	0	0	0	0	0	0	50.0	0	100.0
Foreign -Controlled Firms											
100 or less employees	(11)	15.5	14.8	0	0	46.2	0	0	23.0	0.5	100.0
101-500 employees	(10)	47.0	43.0	0	0	0	0	0	10.0	0	100.0
over 500 employees	(3)	79.1	0	0	0	0	0	0	20.9	0	100.0

* Brackets contain number of innovations

Table A-3

TELECOMMUNICATIONS EQUIPMENT AND COMPONENTS
AVERAGE PERCENTAGE OF GOVERNMENT CONTRIBUTION TO TOTAL FUNDING*
BY CONTROL, BY SIZE

	Innovations Receiving Some Government Funding	Innovations Receiving Some Government Funding as Percent of Total Innovations Not Wholly Funded Internally	Average Percent of Total Funding
		-- (%) --	
Canadian - Controlled Firms			
100 or less employees	16	69.5	41.9
101-500 employees	5	62.5	23.4
over 500 employees	2	100.0	50.0
Total	23	69.7	38.5
Foreign -Controlled Firms			
100 or less employees	6	54.5	33.2
101-500 employees	5	50.0	38.0
over 500 employees	3	100.0	30.0
Total	14	58.3	34.2

* of major innovations receiving some government funding

Table A-4

TELECOMMUNICATIONS EQUIPMENT AND COMPONENTS
GOVERNMENT CONTRIBUTIONS CATEGORIZED BY PER CENT OF TOTAL FUNDING*
BY CONTROL, BY SIZE

	75%+	50%-74%	25%-49%	1%-24%	Total
Canadian - Controlled Firms			Number of Contributions		
100 or less employees	2	5	7	2	16
101-500 employees	0	0	4	1	5
over 500 employees	0	2	0	0	2
Total	2	7	11	3	23
Foreign - Controlled Firms					
100 or less employees	0	1	2	3	6
101-500 employees	0	2	2	1	5
over 500 employees	0	0	2	1	3
Total	0	3	6	5	14
Total	2	10	17	8	37

* of major innovations receiving some government funding

Table A-5

ELECTRICAL INDUSTRIAL EQUIPMENT
CONTRIBUTIONS TO TOTAL FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY BY SOURCE, BY CONTROL, BY SIZE

		Internal	Parent	Private Investors	Bond Issue	Bank: Conventional Loan	Bank: Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
						$ Million					
Canadian - Controlled Firms											
100 or less employees	(7)*	0.4	0.4	0	0	0.2	0	0	0.1	0	1.1
101-500 employees	(3)	0.6	0.6	0	0	0	0	0	0.2	0	1.4
over 500 employees	(0)	0	0	0	0	0	0	0	0	0	0
Total	(10)	1.0	1.0	0	0	0.2	0	0	0.3	0	2.5
Foreign- Controlled Firms											
100 or less employees	(3)	0.3	0.1	0	0	0	0	0	0.1	0	0.5
101-500 employees	(8)	1.6	0.4	0	0	0.1	0	0	0.8	0	2.9
over 500 employees	(2)	12.5	0	0	0	0	0	0	5.8	0	18.3
Total	(13)	14.4	0.5	0	0	0.1	0	0	6.7	0	21.7
Total	(23)	15.4	1.5	0	0	0.3	0	0	7.0	0	24.2

* Brackets contain number of innovations

Table A-6

ELECTRICAL INDUSTRIAL EQUIPMENT
PERCENTAGE DISTRIBUTION OF CONTRIBUTIONS TO TOTAL FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY
BY SOURCE, BY CONTROL, BY SIZE

						Bank					
		Internal	Parent	Private Investors	Bond Issue	Conventional Loan	Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
						--(%) --					
Canadian-Controlled Firms											
100 or less employees	(7)*	37.5	37.9	0	0	16.2	0	0	8.4	0	100.0
101-500 employees	(3)	40.1	43.8	0	0	0	0	0	16.1	0	100.0
over 500 employees	(0)	0	0	0	0	0	0	0	0	0	0
Foreign - Controlled Firms											
100 or less employees	(3)	57.2	20.0	0	0	10.4	0	0	12.4	0	100.0
101-500 employees	(8)	56.8	14.0	0	0	3.5	0	0	25.7	0	100.0
over 500 employees	(2)	68.3	0	0	0	0	0	0	31.7	0	100.0

* Brackets contain number of innovations

Table A-7

ELECTRICAL INDUSTRIAL EQUIPMENT
AVERAGE PERCENTAGE OF GOVERNMENT CONTRIBUTION TO TOTAL FUNDING*
BY CONTROL, BY SIZE

	Innovations Receiving Some Government Funding	Innovations Receiving Some Government Funding as Percent of Total Innovations Not Wholly Funded Internally	Average Percent of Total Funding
		-- (%) --	
Canadian-Controlled Firms			
100 or less employees	2	28.6	22.5
101-500 employees	2	66.7	32.5
over 500 employees	0	0	0
Total	4	40.0	27.5
Foreign - Controlled Firms			
100 or less employees	1	33.3	20.0
101-500 employees	4	50.0	38.8
over 500 employees	2	100.0	23.0
Total	7	53.9	31.5

* of major innovations receiving some government funding

Table A-8

ELECTRICAL INDUSTRIAL EQUIPMENT
GOVERNMENT CONTRIBUTIONS CATEGORIZED BY PER CENT OF TOTAL FUNDING*
BY CONTROL, BY SIZE

	75%+	50%-74%	25%-49%	1%-24%	Total
Canadian-Controlled Firms			Number of Contributions		
100 or less employees	0	0	1	1	2
101-500 employees	0	1	0	1	2
over 500 employees	0	0	0	0	0
Total	0	1	1	2	4
Foreign-Controlled Firms					
100 or less employees	0	0	0	1	1
101-500 employees	0	2	2	0	4
over 500 employees	0	0	1	1	2
Total	0	2	3	2	7
Total	0	3	4	4	11

* of major innovations receiving some government funding

Table A-9

PLASTIC COMPOUNDS AND SYNTHETIC RESINS
CONTRIBUTIONS TO TOTAL FUNDING OF INNOVATIONS NOT WHOLLY FUNDED INTERNALLY
BY SOURCE, BY CONTROL, BY SIZE

		Internal	Parent	Private Investors	Bond Issue	Bank Conventional Loan	Bank Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
						$ Million					
Canadian- Controlled Firms											
100 or less employees	(4)*	0.4	0	0	0	0	0	0	0.3	0	0.7
101-500 employees	(5)	2.2	0	0.1	0	4.3	0	0	0.7	0.1	7.4
over 500 employees	(0)	0	0	0	0	0	0	0	0	0	0
Total	(9)	2.6	0	0.1	0	4.3	0	0	1.0	0.1	8.1
Foreign - Controlled Firms											
100 or less employees	(0)	0	0	0	0	0	0	0	0	0	0
101-500 employees	(4)	1.8	5.6	0	0	0	0	0	0.3	0.2	7.9
over 500 employees	(1)	41.2	0	0	0	0	0	0	0	0	41.2
Total	(5)	43.0	5.6	0	0	0	0	0	0.3	0.2	49.1
Total	(14)	45.6	5.6	0.1	0	4.3	0	0	1.3	0.3	57.2

* Brackets contain number of innovations

Table A-10

PLASTIC COMPOUNDS AND SYNTHETIC RESINS
PERCENTAGE DISTRIBUTION OF CONTRIBUTIONS TO TOTAL FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY
BY SOURCE, BY CONTROL, BY SIZE

						Bank					
		Internal	Parent	Private Investors	Bond Issue	Conventional Loan	Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
						-- (%) --					
Canadian-Controlled Firms											
100 or less employees	(4)*	53.0	0	0	0	5.3	0	0	41.7	0	100.0
101-500 employees	(5)	30.3	0	2.0	0	57.8	0	0	8.9	1.0	100.0
over 500 employees	(0)	0	0	0	0	0	0	0	0	0	0
Foreign-Controlled Firms											
100 or less employees	(0)	0	0	0	0	0	0	0	0	0	0
101-500 employees	(4)	22.5	71.2	0	0	0	0	0	3.6	2.7	100.0
over 500 employees	(1)	100.0	0	0	0	0	0	0	0	0	100.0

* Brackets contain number of innovations

Table A-11

PLASTIC COMPOUNDS AND SYNTHETIC RESINS
AVERAGE PERCENTAGE OF GOVERNMENT CONTRIBUTION TO TOTAL FUNDING*
BY CONTROL, BY SIZE

	Innovations Receiving Some Government Funding	Innovations Receiving Some Government Funding as Percent of Total Innovations Not Wholly Funded Internally	Average Percent of Total Funding
		-- (%) --	
Canadian -Controlled Firms			
100 or less employees	3	75.0	40.0
101-500 employees	3	60.0	32.0
over 500 employees	0	0	0
Total	6	66.7	36.0
Foreign - Controlled Firms			
100 or less employees	0	0	0
101-500 employees	2	50.0	42.5
over 500 employees	0	0	0
Total	2	40.0	42.5

* of major innovations receiving some government funding

Table A-12

PLASTIC COMPOUNDS AND SYNTHETIC RESINS
GOVERNMENT CONTRIBUTIONS CATEGORIZED BY PER CENT OF TOTAL FUNDING*
BY CONTROL, BY SIZE

	75%+	50%-74%	25%-49%	1%-24%	Total
			Number of Contributions		
Canadian-Controlled Firms					
100 or less employees	0	1	2	0	3
101-500 employees	0	1	1	1	3
over 500 employees	0	0	0	0	0
Total	0	2	3	1	6
Foreign-Controlled Firms					
100 or less employees	0	0	0	0	0
101-500 employees	0	0	2	0	2
over 500 employees	0	0	0	0	0
Total	0	0	2	0	2
Total	0	2	5	1	8

* of major innovations receiving some government funding

Table A-13

SMELTING AND REFINING
CONTRIBUTIONS TO TOTAL FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY
BY SOURCE, BY CONTROL, BY SIZE

		Internal	Parent	Private Investors	Bond Issue	Bank: Conventional Loan	Bank: Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
						$ Million					
Canadian-Controlled Firms											
100 or less employees	(1)*	0.1	0	0	0	0	0	0	0	0.1	0.2
101-500 employees	(0)	0	0	0	0	0	0	0	0	0	0
over 500 employees	(0)	0	0	0	0	0	0	0	0	0	0
Total	(1)	0.1	0	0	0	0	0	0	0	0.1	0.2
Foreign-Controlled Firms											
100 or less employees	(2)	0	2.6	0	0	5.2	0	0	0.2	0	8.0
101-500 employees	(1)	12.7	0	6.3	0	0	0	0	0	6.3	25.3
over 500 employees	(2)	45.0	7.6	0	0	74.7	224.1	0	0	37.4	388.8
Total	(5)	57.7	10.2	6.3	0	79.9	224.1	0	0.2	43.7	422.1
Total	(6)	57.8	10.2	6.3	0	79.9	224.1	0	0.2	43.8	422.3

* Brackets contain number of innovations

Table A-14

SMELTING AND REFINING
PERCENTAGE DISTRIBUTION OF CONTRIBUTIONS TO TOTAL FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY
BY SOURCE, BY CONTROL, BY SIZE

						Bank					
		Internal	Parent	Private Investors	Bond Issue	Conventional Loan	Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
						-- (%) --					
Canadian-Controlled Firms											
100 or less employees	(1)*	50.0	0	0	0	0	0	0	0	50.0	100.0
101-500 employees	(0)	0	0	0	0	0	0	0	0	0	0
over 500 employees	(0)	0	0	0	0	0	0	0	0	0	0
Foreign-Controlled Firms											
100 or less employees	(2)	0	32.2	0	0	65.0	0	0	2.8	0	100.0
101-500 employees	(1)	50.0	0	25.0	0	0	0	0	0	25.0	100.0
over 500 employees	(2)	11.6	2.0	0	0	19.2	57.6	0	0	9.6	100.0

* Brackets contain number of innovations

Table A-15

SMELTING AND REFINING
AVERAGE PERCENTAGE OF GOVERNMENT CONTRIBUTION TO TOTAL FUNDING* BY CONTROL, BY SIZE

	Innovations Receiving Some Government Funding	Innovations Receiving Some Government Funding as Percent of Total Innovations Not Wholly Funded Internally	Average Percent of Total Funding
Canadian- Controlled Firms			
100 or less employees	0	0	0
101-500 employees	0	0	0
over 500 employees	0	0	0
Total	0	0	0
Foreign - Controlled Firms			
100 or less employees	1	50.0	8.0
101-500 employees	0	0	0
over 500 employees	0	0	0
Total	1	20.0	8.0

* of major innovations receiving some government funding

Table A-16

SMELTING AND REFINING
GOVERNMENT CONTRIBUTIONS CATEGORIZED BY PER CENT OF TOTAL FUNDING*
BY CONTROL, BY SIZE

	75%+	50%-741	25%-49%	1%-24%	Total
			Number of Contributions		
Canadian-Controlled Firms					
100 or less employees	0	0	0	0	0
101-500 employees	0	0	0	0	0
over 500 employees	0	0	0	0	0
Total	0	0	0	0	0
Foreign-Controlled Firms					
100 or less employees	0	0	0	1	1
101-500 employees	0	0	0	0	0
over 500 employees	0	0	0	0	0
Total	0	0	0	1	1
Total	0	0	0	1	0

* of major innovations receiving some government funding

Table A-17

CRUDE PETROLEUM PRODUCTION
CONTRIBUTIONS TO TOTAL FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY
BY SOURCE, BY CONTROL, BY SIZE

		Internal	Parent	Private Investors	Bond Issue	Bank Conventional Loan	Bank Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
						$ Million					
Canadian-Controlled Firms											
100 or less employees	(3)*	0	0	0	0	0	0	0	0	2.2	2.2
101-500 employees	(0)	0	0	0	0	0	0	0	0	0	0
over 500 employees	(0)	0	0	0	0	0	0	0	0	0	0
Total	(3)	0	0	0	0	0	0	0	0	2.2	2.2
Foreign-Controlled Firms											
100 or less employees	(1)	2.5	0	0	0	0	0	0	6.2	3.7	12.4
101-500 employees	(3)	17.7	189.8	0	0	0	0	0	15.8	63.2	286.5
over 500 employees	(3)	1.8	0.3	0	0	0	0	0	0	0.5	2.6
Total	(7)	22.0	190.1	0	0	0	0	0	22.0	67.4	301.5
Total	(10)	22.0	190.1	0	0	0	0	0	22.0	69.6	303.7

* Brackets contain number of innovations

Table A-18

CRUDE PETROLEUM PRODUCTION
PERCENTAGE DISTRIBUTION OF CONTRIBUTIONS TO TOTAL FUNDING OF MAJOR INNOVATIONS NOT WHOLLY FUNDED INTERNALLY
BY SOURCE, BY CONTROL, BY SIZE

						Bank					
		Internal	Parent	Private Investors	Bond Issue	Conventional Loan	Debentures/ Preferred	Venture Capital Firm	Government	Other	Total
						-- (%) --					
Canadian - Controlled Firms											
100 or less employees	(3)*	0	0	0	0	0	0	0	0	100.0	100.0
101-500 employees	(0)	0	0	0	0	0	0	0	0	0	0
over 500 employees	(0)	0	0	0	0	0	0	0	0	0	0
Foreign - Controlled Firms											
100 or less employees	(1)	20.0	0	0	0	0	0	0	50.0	30.0	100.0
101-500 employees	(3)	6.2	66.2	0	0	0	0	0	5.5	22.1	100.0
over 500 employees	(3)	67.5	13.6	0	0	0	0	0	0	18.9	100.0

* Brackets contain number of innovations

Table A-19

CRUDE PETROLEUM PRODUCTION
AVERAGE PERCENTAGE OF GOVERNMENT CONTRIBUTION TO TOTAL FUNDING*
BY CONTROL, BY SIZE

	Innovations Receiving Some Government Funding	Innovations Receiving Some Government Funding as Percent of Total Innovations Not Wholly Funded Internally	Average Percent of Total Funding
		-- (%) --	
Canadian - Controlled Firms			
100 or less employees	2	66.7	10.0
101-500 employees	0	0	0
over 500 employees	0	0	0
Total	2	66.7	10.0
Foreign - Controlled Firms			
100 or less employees	1	100.0	50.0
101-500 employees	2	66.7	33.0
over 500 employees	0	0	0
Total	3	42.9	38.7

* of major innovations receiving some government funding.

Table A-20

CRUDE PETROLEUM PRODUCTION
GOVERNMENT CONTRIBUTIONS CATEGORIZED BY PER CENT OF TOTAL FUNDING*
BY CONTROL, BY SIZE

	75%+	50%-74%	25%-49%	1%-24%	Total
	Number of Contributions				
Canadian-Controlled Firms					
100 or less employees	0	0	0	2	2
101-500 employees	0	0	0	0	0
over 500 employees	0	0	0	0	0
Total	0	0	0	2	2
Foreign-Controlled Firms					
100 or less employees	0	1	0	0	1
101-500 employees	0	1	0	1	2
over 500 employees	0	0	0	0	0
Total	0	2	0	1	3
Total	0	2	0	3	5

* of major innovations receiving some government funding

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