

# **Skills Research Initiative Initiative de recherche sur les compétences**

## **International Labour Mobility and Knowledge Flow Patterns**

Alexander Oettl (University of Toronto)

Ajay Agrawal (University of Toronto)

Working Paper 2006 D-20

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## **Abstract**

Knowledge flows enhance firm productivity and economic growth. Prior research has found that knowledge flows are highly localized, and this finding has been partially attributed to social relationships that exist between co-located inventors. So, what happens to knowledge flows when inventors move? We find evidence that international labour mobility does indeed influence knowledge flow patterns. Specifically, we find that an immigrant inventor's new country benefits from their arrival above and beyond the benefits enjoyed by the firm that recruited them; we refer to this phenomenon as "National Learning by Immigration." Furthermore, our results suggest that the firm that lost the inventor also gains by receiving increased knowledge flows from that individual's new firm and country, which we refer to as "Firm Learning from the Diaspora." Moreover, we find that the latter effect is significantly stronger when the mover moves across borders but within the same multi-national firm.

## **Résumé**

Les flux de savoir stimulent la productivité des entreprises et la croissance économique. Des études antérieures ont montré que les flux de savoir sont fortement concentrés, et ce fait a été attribué, en partie, aux relations sociales qui existent entre les inventeurs d'un même endroit. Alors, qu'advient-il des flux de savoir lorsque les inventeurs déménagent? Les auteurs ont trouvé des données selon lesquelles la mobilité internationale de la main-d'œuvre a une réelle incidence sur la structure des flux de savoir. Plus précisément, le pays d'accueil d'un immigrant profite de cette arrivée au-delà des avantages qui reviennent à l'entreprise qui l'a embauché; les auteurs appellent ce phénomène « l'apprentissage national par l'immigration ». De plus, les résultats de l'étude laissent supposer que l'entreprise qui a perdu l'inventeur gagne quand même puisqu'elle reçoit des flux de savoir de la nouvelle entreprise de cet employé et de son nouveau pays d'accueil; les auteurs désignent ce phénomène « l'apprentissage de l'entreprise grâce à la diaspora ». En outre, ce dernier effet est beaucoup plus fort lorsque l'employé déménage d'un pays à l'autre, mais qu'il reste au sein de la même multinationale.



## 1 Introduction

We examine the relationship between international labour mobility and knowledge flows. Knowledge flows are economically important. In fact, contemporary economic theory has focused on knowledge spillovers – knowledge flows that occur outside of market mechanisms – as the central determinant of economic growth (Romer 1986, 1990). However, given their importance, the mechanisms by which knowledge flows are surprisingly little understood.

Our lack of understanding about these mechanisms is not due to a lack of interest. Rather, knowledge flows are notoriously difficult to measure. In fact, Krugman (1991) famously argued *against* focusing on knowledge flows when developing economic models because “[k]nowledge flows... are invisible; they leave no paper trail by which they may be measured and tracked, and there is nothing to prevent the theorist from assuming anything about them that she likes.”

The work of Jaffe et al (1993) pointed, however, to an important exception. They argued that “[k]nowledge flows do sometimes leave a paper trail in the form of patent citations.” Since then, a steady stream of empirical research has developed, largely based on patent citation data, which has begun to shed light on how knowledge flows work. In particular, several studies have reported results strongly suggesting that flows associated with scientific knowledge are surprisingly geographically localized (Jaffe et al, 1993; Audretsch and Feldman, 1996; Almeida and Kogut, 1999; Agrawal and Cockburn, 2003; Thompson and Fox-Kean, 2005). The degree to which scientific knowledge flows are localized is surprising because of the priority to publish that characterizes the institution of Science (Dasgupta and David, 1987, 1994).

Given the broad geographic distribution of scientific activity and the strong incentives to disseminate new knowledge quickly through international journals and conference presentations, why are spillovers more likely to occur amongst co-located scientists? Recent empirical evidence suggests that knowledge flows are partly mediated by social relationships (Zucker et al, 1998; Almeida and Kogut, 1999; Agrawal et al, 2003; Singh, 2005) and, since social relationships are more likely between co-located individuals, knowledge flows are localized.

To the extent that this is true, what are the implications for the relationship between labour mobility and knowledge flows? What happens when inventors move? If social relationships between co-located individuals are important conduits for knowledge flows, what happens to those knowledge flows when individuals are relocated? To what extent are knowledge flows between countries more likely when individuals have moved between them? The objective of this study is to empirically examine the influence of international labour mobility on knowledge flows.

One objective of this research is to contribute to the growing literature on the implications of international labour mobility on Canadian public policy (Harris, 2004; Gera, Laryea, and Songsakul, 2004). While this study focuses on a particular segment of the labour market - scientists and engineers - some of the findings may be generalized across a broader spectrum of skilled workers. Regardless, the labour segment under investigation is a necessary input for productivity gains and competition at both industry and national levels. Another objective of this research is to enhance our understanding of the determinants of patterns of knowledge flows which will, in turn, also increase our understanding of the mechanisms that drive economic growth.

We address three specific questions in this paper, each with respect to an inventor moving from Firm 1 in Country 1 to Firm 2 in Country 2. First, does Country 2 benefit from this move by receiving increased knowledge flows from Firm 1 (the mobile inventor's prior domicile) above and beyond the benefits received by the hiring Firm 2? We refer to this phenomenon as National Learning by Immigration. Second, does Firm 1 benefit from this move by receiving increased knowledge flows from Firm 2 (the mover's new firm) and more generally from Country 2 (the mover's new domicile)? We refer to this as Firm Learning from the Diaspora. Finally, are these effects on knowledge flows caused by mobility any different when the cross-border move occurs within the same firm?

To be clear, we remain agnostic as to the socializing mechanism that facilitates knowledge flows. We treat co-location (inventors residing in the same "foreign" country) as a sort of social treatment that simply increases the probability of forming a social relationship which, in turn, increases the probability of knowledge flows. In other words, we don't specify how relationships are actually formed. That said, it seems likely that



relationships are formed through formal scientific and professional networking, but also through informal networking with neighbors and others encountered in nonprofessional social settings that also result, nonetheless, from being co-located.

While several papers have focused on the link between social relationships and knowledge flows (Zucker et al, 1998; Singh, 2005), only a few have focused on labour mobility and knowledge flows. Our work builds primarily on these. In particular, Almeida and Kogut (1999) present results suggesting that regions, such as Silicon Valley, that experience higher than average levels of inter-firm mobility tend to also experience a greater degree of knowledge localization, implying a direct relationship between labour mobility and knowledge flows. Song et al (2003) find evidence of firm “learning-by-hiring” and show that this phenomenon is most significant when the recruited engineers are used for exploring knowledge that is technologically distant from the hiring firm’s area of expertise. Agrawal et al (2003) report findings that suggest knowledge generated by an inventor that has moved locations is more likely to flow back to that inventor’s prior city than if the inventor had never lived there (“gone but not forgotten”).

Our study builds on this prior work, making the following three primary contributions. First, we build on the learning-by-hiring finding by examining the degree to which a mover’s recipient *country* increases their propensity to draw knowledge from the mover’s prior firm. In other words, we explore the degree to which the effect of the mover on knowledge flow works beyond the hiring firm and spills over to the recipient country. Second, we build on the “gone but not forgotten” result by examining the degree to which the mover’s prior firm (rather than their city) receives increased knowledge flows from the mover’s new firm and, more generally, their new country. Finally, we examine the degree to which both of these effects are mediated by cross-border moves that occur within a single firm.

The remainder of the paper is organized as follows. In the next section, we describe our empirical methodology, including a discussion of our econometric approach and the particular measures we use. In Section 3, we detail how our dataset is constructed. In Section 4, we provide descriptive statistics associated with our key variables, namely those that measure labour mobility and knowledge flows, as well as the

regression results associated with the tests for each of our hypotheses. Finally, we conclude in Section 5 by offering our interpretation of the results with respect to their implications for policy.

## 2 Methodology

Our basic objective is to deepen our understanding of the relationship between cross-border labour mobility and knowledge flows:

$$KnowledgeFlows = f(LaborFlows)$$

For measurement purposes, we use patent citation counts as a proxy for knowledge flows and counts of “patenting inventors” that cross national borders as a proxy for labour flows. We describe the construction of these and other measures in Section 3 below. Here, we describe our method for empirically exploring the relationship between these two variables.

Specifically, we seek to address two questions. First, to what degree are national knowledge inflows influenced by immigration? And second, to what degree are firm knowledge inflows influenced by the migration patterns of the company’s diaspora? In order to address these questions, we design our study around the inventor from Firm 1 in Country 1 who moves to Firm 2 in Country 2.

Our unit of analysis is the firm-country dyad. That is, the unit of analysis is determined by the specific firm from which the mover moved (Firm 1 in Country 1) and the country to which the mover moved (Country 2). Therefore, we distinguish between a mover who leaves Xerox Canada for Germany and one that leaves Xerox USA for Germany. We use the same unit of analysis to address our two main research questions.

We explore these questions empirically using a 21-year panel dataset and the following base specification:

$$E[K|M, X, C] = \exp(\alpha(M) + \beta(X) + C + \varepsilon)$$

where the expected knowledge flow ( $K$ ) is an exponential function of the number of Movers ( $M$ ) from a *previous* time period, a vector of control variables ( $X$ ), a full set of dyad fixed effects ( $C$ ), and an error term  $\varepsilon$ .

Since we are attempting to estimate the degree to which labour flows influence knowledge flows, it is important to isolate any idiosyncratic heterogeneity that may exist between dyad members. If we believe this heterogeneity to be largely time-invariant, then a fixed effects model, which estimates coefficients using within-dyad variation, will yield consistent estimates (Wooldridge, 2002). Consequently, dyads with no variation in knowledge flows across our sample time period are dropped.

While fixed effects estimation captures time-invariant heterogeneity, anything that is time varying must also be controlled for. We include patent flow measures which capture a firm's and a country's patenting output, where higher patenting entities are believed to be more likely to receive or provide knowledge spillovers. Additionally, patent stock variables for both firms and countries are used in our regression analyses to capture the tendency of firms or countries with larger stocks of patents to be more likely to provide knowledge spillovers. Furthermore, we include measures that control for the degree to which movers themselves generate knowledge flows (since we are seeking to estimate the indirect effect of that mover). Lastly, a technological similarity index is constructed to control for time varying characteristics between the two members of the dyad that may influence their propensity to receive or provide knowledge flows to one another.

Returning to our specific research questions, we are first interested in estimating the degree to which Country 2's knowledge flows are influenced by a mover who arrives from Firm 1. This is our National Learning from Immigration question. For the dependent variable, we use a count of the number of citations per year made by the receiving country to the immigrant's prior firm over the 21-year period under investigation (1980-2000, inclusive). We also are interested in estimating the degree to which Firm 1's knowledge flows are influenced by the location decision of the mover who left. This is our Firm Learning from the Diaspora question. To examine this phenomenon, we use as our dependent variable a count of the number of citations per year made by the mover's old firm to the mover's new firm (and country).

We focus our attention on the statistical significance and economic importance of the coefficient  $\alpha$ . We interpret the value of this coefficient as indicating the degree to which movers influence knowledge flows. A serious concern in these types of studies, however, is the potentially endogenous relationship between labour mobility and knowledge flows. While we do employ a lagged data structure such that we compare labour

mobility in one period with knowledge flows in the following period, we interpret our results cautiously and discuss this issue further in the Results section.

### **3 Data**

Since we are interested in knowledge flows associated with innovation, we begin with a dataset that is commonly used for measuring this phenomenon: the patent dataset compiled by the United States Patent and Trademark office and refined by Hall and others associated with the National Bureau of Economic Research (Jaffe and Trajtenberg, 2002). Specifically, we are interested in the relationship between international labour mobility and knowledge flows. As such, we seek to construct a dataset that is conditioned on labour movement so that we can then examine the effect of that movement on knowledge flows.

We identify “movers” in these data by examining the inventor names on all patents issued during the years 1975-2004, inclusive. Specifically, we search for inventor names that are associated with different country locations on different patents. So, if someone is listed on a patent as an inventor located in Germany in 1991 and also listed on a patent as an inventor located in Canada in 1993, we flag this inventor as a potential mover.

Matching inventors purely on their names introduces the risk of type I errors (inventors may use multiple spelling permutations of their name such that we miss actual movers) and type II errors (different inventors may have the same name such that we flag someone as a mover who is not). We do not address type I errors and thus our sample is a conservative estimate of the overall levels of inventor migration. However, since we do not expect the likelihood of recording different name spellings across multiple patents to be correlated with citation propensities, we are not concerned about this measurement error biasing our main result.

To minimize type II errors, we add the sampling restriction that the inventor’s multiple patents must be in similar fields as defined by 1) a match at the international classification subclass level (there is normally only one international classification per patent), 2) a match at the US classification primary three-digit level, or 3) a match between one of the patent’s primary three-digit classifications and one of the secondary classifications of the other patent.

Of the approximately 3.2 million patents issued between 1976 and 2004, we identify 37,200 inventor movement instances.<sup>1</sup> These moves form the basis of our unit of analysis, the topic to which we turn next.

As described in the Methodology section above, we use the Firm-Country as our unit of analysis. We collect data for a variety of measures associated with this dyad, including citations, movers, patent stocks, etc., for each of the years 1980-2000, inclusive. It should be noted that “firm” refers both to private sector enterprises as well as to universities and public research institutions, although traditional firms from the private sector make up the large majority of the sample.

Our objective is to measure the impact of mobility on subsequent knowledge flows. In an effort to identify the effect of movers, we limit the inclusion of dyads to only those where no previous inventors moved during the prior period 1975-1979. Furthermore, we require that the sending firm patented at least once between the period of 1975 and 1979 as well as between 2001 and 2004. This ensures that the firm was at risk during our time period of analysis; that is, it was founded by 1980 and still existed in 2000.

After imposing the data restrictions above, we are left with 5,485 movers that generate 2,154 unique dyads. Since we collect 21 years of data (1980-2000, inclusive) for each dyad, our panel dataset consists of  $(21 \times 2154)$  45,234 observations.

Since we explore two basic research questions (the third is a derivative of these two), we employ two different but related dependent variables. For measuring the knowledge flows from Firm 1 to Country 2 (National Learning by Immigration), we use the measure  $Citations_{CjFit}$ , which is a count of the number of times inventors in Country  $j$  cite Firm  $i$  in year  $t$ . For measuring the reverse knowledge flows from Country 2 to Firm 1 (Firm Learning from the Diaspora), we use the measure  $Citations_{FiCjt}$ , which is a count of the number of times Firm  $i$  cites Country  $j$  in year  $t$ . Inventor self-cites are removed from the data and not included in these citation counts.<sup>2</sup>

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<sup>1</sup> If the same inventor moves from country A to country B and then to country C, we observe two direct moves (from A to B and B to C) and one indirect move (from A to C). We do not distinguish between direct and indirect moves for the purposes of this analysis; however, it is interesting to note that of the 37,200 moves, 17,743 are direct.

<sup>2</sup> Also, if a cited patent has multiple inventors located in multiple countries, each country is counted.

Thus, we use patent citations as a proxy for knowledge flows. However, patent citations are not straightforward to interpret in terms of communication between inventors and therefore the signal-to-noise ratio for this measure is likely to be low. Patents cite other patents as “prior art,” with citations serving to delineate the property rights conferred. Some citations are supplied by the applicant, others by the patent examiner, and some patents may be cited more frequently than others because they are more salient in terms of satisfying legal definitions of prior art rather than because they have greater technological significance. Cockburn, Kortum, and Stern (2002) report, for example, that some examiners have “favourite” patents that they cite preferentially because they “teach the art” particularly well.

Nonetheless, Jaffe *et al.* (2002) surveyed cited and citing inventors to explore the “meaning of patent citations” and found that approximately one-quarter of the survey responses corresponded to a “fairly clear spillover,” approximately one-half indicated no spillover, and the remaining quarter indicate some possibility of a spillover. Based on their survey data they conclude that “...these results are consistent with the notion that citations are a noisy signal of the presence of spillovers. This implies that aggregate citation flows can be used as proxies for knowledge-spillover intensity, for example, between categories of organizations or between geographic regions” (p. 400). Moreover, as noted in the text, we allow for indirect social relationships that are not captured in the Jaffe survey. So, for example, if inventor A has a relationship with B, and B has a relationship with C, it is possible for B to facilitate a knowledge exchange between A and C since she has a social relationship with both. In fact, this is the type of indirect mechanism that we have in mind when we explore the effect of the mover on influencing knowledge flows beyond the boundary of their hiring firm and spilling over to other inventors in the recipient country.

Our key explanatory variable for both research questions is  $Movers_{FIC2}$ , which is a count of the number of inventors that have moved from Firm  $i$  to Country  $j$  between 1980 and year  $t$ . It is important to note that while our dependent variable is a flow measure (the number of citations in year  $t$ ), our main right hand side variable is a stock measure (the number of movers by year  $t$ ). We are interested in the cumulative effect of movers on knowledge flows over time.

We control for the overall innovation level of the firm from which the mover moved by including  $\text{PatentStock}_{Fit}$ , which is a count of the cumulative number of patents granted to Firm  $i$  between 1975 and year  $t$ , inclusive. Since we are interested in national learning in the former question, rather than firm learning as measured in Song et al (2003), we control for the number of citations the mover's new company makes to their old company with  $\text{Citations}_{FjFit}$ . Thus, we are able to interpret the coefficient on  $\text{Movers}_{F1C2}$  as the effect of labour mobility on knowledge flows to the recipient country, above and beyond the benefits to the recruiting firm.

Finally, we also include a measure of technological similarity in some of our estimations.  $\text{TechnologyOverlap}_{ijt}$  is a measure of the technological similarity between firm  $i$  and country  $j$  at time  $t$ :

$$\text{TechnologyOverlap}_{ijt} = \frac{\sum_s p_{ist} p_{jst}}{\sqrt{\sum_s (p_{ist})^2 \sum_s (p_{jst})^2}}$$

where  $p_{ist}$  is the share of patents issued to firm-country  $i$  up until time  $t$  (from 1975) that belong to NBER subclassification  $s$ . A value of one denotes a perfect technological overlap between firm  $i$  and country  $j$ , and a value of zero denotes no overlap.

## 4 Results

We begin by providing descriptive statistics of our key measures - labour flows and knowledge flows - with respect to the Canadian data. In addition to descriptive statistics, we provide detailed information on the companies from which movers moved. We then examine descriptive statistics at an international level, such that these measures, and Canada's relative position, can be considered in a global context. Next, we offer summary statistics of all variables used in the multivariate analyses. Finally, we report regression results and discuss our interpretation of these estimates.

#### 4.1 Descriptive Statistics: Canada

We begin by examining the number of inventors that moved to and from Canada during the period under investigation.<sup>3</sup> From Table 1 (row 4), we see that 133 inventors moved away from Canada, the majority of whom (85%) migrated to the United States. The organizations that lost these inventors are listed in Table 2. Foreign subsidiaries, such as Xerox, 3M, and IBM, seemed to lose the greatest number of inventors, most of whom moved to the United States. However, government organizations, such as the Alberta Research Council, Hydro Quebec, and the Pulp and Paper Research Institute of Canada also lost inventors who chose to leave the country.

Similarly, universities such as the University of Alberta, Queen's University, and the University of Saskatchewan lost inventors. Interestingly, no movers from the large urban research universities, such as the University of Toronto, the University of British Columbia, or McGill University, appear on our list. Finally, Canadian-based companies such as Husky Injection Molding Systems, Labatt Brewing Company, and Magna International also lost inventors who moved out of the country. One such company, Nortel, had employees move to five different countries during the period under investigation: France, Belgium, Japan, Israel, and Poland, but interestingly none moved to the United States.

However, inventors did not only leave Canada; they also entered. In fact, more inventors of the type measured here came to rather than left the country. Returning to Table 1 (column 4), we see that 269 inventors entered Canada, double the number that left. Once again, the majority (76%) came from the United States. Other countries, including Germany, Great Britain, and Japan, were also sources of talent for Canada, although in terms of numbers they supplied an order of magnitude less than the US.

In terms of the foreign companies that lost the greatest number of inventors who moved to Canada, the top of the list looks remarkably similar to the top of the list of Canadian subsidiaries that also lost inventors (see

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<sup>3</sup> It is important to recall that we only count a certain type of mover since we condition our dataset on movers from firms with at least one patent between 1975 and 1979 and at least one patent after 2000. In other words, we focus on movers from enduring firms and do not count movers from companies that started after 1980, or that folded, were acquired, or changed names before 2000.



Table 3). US firms, such as Xerox, IBM, and 3M were the primary losers of talent to Canada, but many other foreign firms also lost inventors.

Next, we turn to knowledge flows that occurred to and from Canada. As described earlier, knowledge flows to Canada are measured in terms of citations made by inventors located in Canada to prior knowledge generated in other countries. Table 4 (row 4) shows that inventors located in Canada made 196,139 citations to prior inventions in other countries.<sup>4</sup> Similar to the flow of inventors, the majority of knowledge flows came from the United States (69%). Overall, Canada was a net importer of knowledge as it “imported” 14% more knowledge than it “exported.”

Comparing general mover statistics with those associated with knowledge flows, we notice some interesting relationships. First, although almost as many movers to Canada came from Germany and Great Britain as came from Japan, these two countries were each the source of less than half the knowledge flows that came from Japan to Canada. Second, some countries that were the source of significant knowledge flows to Canada were not the source of any inventors (as picked up by our measurements), such as Taiwan, South Korea, and Finland. Finally, these statistics make clear the limitations of these patent data: The data do not show any inventors moving from India to Canada during this period and, in terms of knowledge flows, only 52 citations were made to Indian inventions (Agrawal et al, 2005).

## **4.2 Descriptive Statistics: Worldwide**

Moving beyond the Canadian statistics, we return to Tables 1 and 4 to examine worldwide trends in labour mobility and knowledge flows. We see that the main net exporters of inventors with large company experience, in terms of absolute numbers, are the United States, Japan, and Germany. In comparison, the main net exporters of knowledge flows are Japan, Germany, France, and Great Britain. Conversely, the main net importers of inventors are Taiwan, Belgium, and Canada and the main net importers of knowledge flows are the United States, South Korea, and Taiwan. From these descriptive data, it is difficult to tell whether there is a

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<sup>4</sup> Recall that we only count citations to patents issued in 1976 or later.

relationship between labour mobility and knowledge flows. We turn next to regression analysis to examine this further.

### 4.3 Summary Statistics

In Table 5, we present general summary statistics for all variables. We see that, on average, the mover's original firm (Firm 1) produces approximately 100 patents per year. In addition, this firm cites the mover's new country approximately 19 times per year, of which just over one citation (1.32) is made to the mover's new firm and an even smaller fraction of a citation (0.03) is made to the mover. In terms of the reverse, we see that on average the mover's new country cites her old firm about 23 times per year. Also, we see that there is, on average, less than one mover (0.81) at the receiving firm in any given year.<sup>5</sup>

### 4.4 National Learning by Immigration

Table 6 presents panel regression results to address the National Learning by Immigration question in which our dependant variable is the flow of knowledge from Firm 1 to Country 2 as measured by patent citations from Country 2 to Firm 1. We employ maximum likelihood negative binomial regression analysis, which is a common estimation technique with these types of count data. The patent stock of Firm 1, defined as the cumulative count of all patents issued to the firm up until time  $t$ , is included in all regressions to control for the influence of a firm's patenting behavior on its likelihood of being cited. In addition, Firm-Country dyad specific heterogeneity is accounted for using a fixed effect estimation, where the variation in knowledge flow within the dyad group is used to estimate the coefficients. Consequently, dyads which exhibit no variation in knowledge flows across the time series of the panel are dropped from the sample during estimation.

Columns 1 through 6 provide fixed effect negative binomial estimation results; column 7 estimates the specification without fixed effects but with year effects, while column 8 estimates the specification with a zero inflated negative binomial approach (ZINB). ZINB, as developed by Greene (1994), assumes that the dependent variable consists of two states that are unknown to the econometrician. In the first regime, the likelihood of a

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<sup>5</sup> Recall that the mover variable is a stock measure and thus records the cumulative number of movers since 1980.

variable taking on a value above zero is highly unlikely, while in the second regime, the variable follows a poisson distribution, where the variable can take on values of both zero and greater. As a result, zero inflated negative binomial estimation involves two distinct parts. The first part distinguishes which regime the observation falls into, in turn “inflating” the zero. This process is normally estimated using a logit regression. With this first step accomplished, a negative binomial regression can then be used to provide coefficient estimates. Both coefficients are estimated using maximum likelihood, but only the coefficients from the second stage of the inflation, the negative binomial results, are reported in our tables. These results are shown in column 8.

As can be seen across the first six columns, the number of movers who have moved from Firm 1 to Country 2 has a positive and statistically significant effect on the level of knowledge sourced from Firm 1 by Country 2.<sup>6</sup> Since all independent variables are entered as levels, the coefficients are interpreted as the percentage change in the dependent variable, given a one unit increase in the independent variable. For column 1, our base specification, where we model knowledge flows from Firm 1 to Country 2 as a function of movers from Firm 1 to Country 2, controlling for the patent stock of Firm 1, the addition of one new mover from Firm 1 to Country 2 results in an approximately 4% increase in Country 2’s level of knowledge acquisition from Firm 1. In other words, a mover from Firm 1 increases the number of citations made from inventors in Country 2 to Firm 1 by 4%. While the magnitude of this coefficient may seem small, it should be noted that this is the extent to which the country as a whole gains from the immigration of a single mover.<sup>7</sup>

In column 2, we add a control for the level to which the knowledge flows from Firm 1 to Country 2 are being generated by the mover herself. That is, if the majority of knowledge flows are being generated by the

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<sup>6</sup> Throughout the paper we use the stock of movers that moved during the period 1980 through time t-1, rather than the count of movers at time t-1 (the flow). Using a stock measure allows us to capture the cumulative effect of movers on a firm over time, but in doing so violates the independence assumption with these data. Estimating the model using the flow of movers at time t-1 instead of the stock *increases* the magnitudes of all coefficients by a factor of approximately two, while retaining equal or greater levels of statistical. We report the stock measures as they are the more conservative of the two.

<sup>7</sup> We also consider the possibility that total bilateral trade in knowledge is an important determinant of knowledge flow patterns. We test this by running regressions that include knowledge flows from country 2 to firm 1 as well as total bilateral flows between Firm 1 and Country 2. The main results remain the unchanged, although the magnitude of the estimated coefficient on movers from Firm 1 to Country 2 increases slightly and the coefficients on the newly added flow measures are negative; all parameters are statistically significant at the 1% level. These results are available from the authors upon request.

mover, then it is hard to say that the country has learned anything from the immigrant inventor. Column 3 controls for the extent to which the increase in knowledge flows that result from migration are being captured by the new firm of the mover. Once again, if the increase in knowledge flows is being entirely captured by the mover's new firm, then although this provides evidence in support of the learning-by-hiring argument, it does little to support our National Learning by Immigration hypothesis. After controlling for all these effects, the main result persists.

In column 4, we include a control for the technological overlap between Firm 1 and Country 2 in order to capture time varying characteristics between the two dyad members that are not captured by the fixed effects estimations. The total number of observations drops since 194 dyad years had no technological overlap index. Since the technological overlap measure depends on patenting activity, if either a country or a firm does not patent in a particular year, the index cannot be constructed, and as such, the observation is dropped from analysis. In column 5, we include the three control variables that were added in serial over the previous three columns. Our main result remains.

In column 6, we include as an additional robustness check the degree to which movers from Country 2 to Firm 1 influence knowledge flows from Firm 1 to Country 2. In column 7, we repeat the specification in column 6, this time without running fixed effects. The benefit of this is that the observations that were previously dropped due to no variation across time in knowledge flows are now included. In column 8, we estimate the specification using ZINB. Throughout, the main result persists.

#### **4.5 Firm Learning from the Diaspora**

To investigate the Learning from the Diaspora question, we turn our attention to Table 7. The first four columns estimate the influence of the movement of an inventor from Firm 1 to Country 2 on knowledge flows from Country 2 to Firm 1. In columns 5 through 8, we separately test the extent to which knowledge flows from the mover's new firm (Firm 2) to their old firm (Firm 1) increase with inventor mobility.

Column 1 lays out the basic Learning from the Diaspora specification, where knowledge flows from Country 2 to Firm 1 are a function of the number of movers to Country 2, the yearly patenting activity of Firm 1,

and the patent stock of Country 2. Time invariant dyad heterogeneity is controlled for using fixed effects. Column 2 augments this specification by including three additional controls. First, cites by Firm 1 to the mover controls for the possibility that the increase in knowledge flows to Firm 1 is driven by citations to the mover specifically, such that Firm 1 is not learning from movers' new environment but just from movers themselves. Second, Firm 1's citations to Firms 2 controls for flows from the mover's new firm; we are interested in the degree to which movers increase flows from their new country not just from the firm to which they move. Finally, technological overlap controls for time variant dyadic heterogeneity in technology profile.

Column 3 includes a measure with the running count of the number of reverse movers from Country 2 to Firm 1. Column 4 replicates the previous specification, without fixed effects, but it does include time effects and relies entirely on the technological overlap measure to capture dyadic heterogeneity. A ZINB estimation technique is once again used here. Our main result persists throughout.

The last four columns shift from the Firm-Country to the Firm-Firm level of analysis, allowing us to examine the effect of movers on flows from their new firms back to their old firms. Column 5 establishes the base case, controlling for cites by Firm 1 to the mover, the yearly patenting activity of Firm 1, and the patent stock of the mover's new firm.<sup>8</sup> We add the technological overlap control in column 6 and reverse movers in Column 7. In column 8, we again employ ZINB estimation. These estimations suggest that movers cause an approximately 4% increase in knowledge flows from the firm they move to back to their prior firm.

#### **4.6 Firm Learning from the Diaspora: Examining the Effect of Within-Firm Movers**

We further explore Learning from the Diaspora in Table 8. In this case, we focus on movers that move across borders but remain working for the same firm. In other words, they locate to a new location within the same multi-national company. We use the same estimation technique and specifications as in Table 7. However, we see the coefficient on movers is approximately two to three times greater than in Table 7. Knowledge flows from the mover's new firm to their old firm are significantly greater when the inventor moves within firms.

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<sup>8</sup> Recall that Firm 1 may have multiple movers to Country 2. In this case, "patent stock" is the sum of the patent stocks of each recipient firm in Country 2.

This measure indicates that firms are indeed managing the knowledge flows associated with their mobile workers more effectively than when left to normal market forces.

#### 4.7 Causality

We have interpreted the statistical correlation between labour flows and knowledge flows as the result of a causal relationship. That is, we assume labour flows cause knowledge flows. Of course, the econometrician must address issues of potential endogeneity and omitted variable bias when making such claims. We discuss these issues here.

We acknowledge potential endogeneity concerns, particularly with respect to National Learning by Immigration. While we assume that the movement of inventors from Firm 1 to Country 2 causes an increase in knowledge flows from Firm 1 to Country 2, it could be that an increase in knowledge flows causes mobility. For example, because more inventors in Country 2 are building on the ideas of Firm 1, and possibly even on the potential mover specifically, the mover has a higher propensity to be attracted to Country 2.

Perhaps more likely is an omitted variable bias. For example, knowledge flows and labour flows might both be correlated with national technology policy. For example, a country that initiates a policy to foster a semiconductor industry by way of research grants, subsidies, and tax incentives, might stimulate activity in this technology area that both increases the absorptive capacity of the nation such that its inventors cite foreign inventors more frequently and also increases the propensity for local firms to hire related inventors from abroad.

Ideally, to address these concerns, we would have an instrument that is correlated with movers but not with citations. In the absence of such an instrument, we rely on a lagged data structure and a control for technology overlap. We describe these approaches next.

First, we employ a lagged measure of labour mobility in our regression models. In other words, while we measure knowledge flows at time  $t$ , we measure labour flows at time  $t-1$ . We employ this lagged time structure to reflect the causal relationship that we believe exists between labour and knowledge flows. However, our measures are messy, particularly for movers. Recall that we do not actually know the precise year that a mover moved. We only know the last year they applied for a patent in their prior country and the first year they

applied for a patent in their new country. In other words, we may be late in estimating when they actually moved but never early. However, this noise in the data will bias our results downwards.

Second, we include a control for technology overlap. In other words, if either a firm or a country changes suddenly (in response to a new policy, for example), such that the composition of its technological activity changes and becomes more similar to that of the other side in the dyad, this will be captured by our technology overlap measure. In this case, the coefficient on technology overlap should capture the change in knowledge flows as opposed to the coefficient on movers. Of course, we also employ firm-country fixed-effects, but these only capture time-invariant characteristics of the dyad, such as distance.

## **5 Conclusions**

We have found preliminary evidence of National Learning by Immigration and Firm Learning from the Diaspora. These phenomena have implications for national policy and firm strategy. We speculate about these implications here.

Countries benefit from receiving immigrant inventors. Not only do recruiting firms enjoy the direct fruits of their labour, but benefits from the immigrant inventor spill over to other organizations in the country. Although we offer no evidence regarding how or why this occurs, we speculate that movers raise awareness amongst their new innovator neighbors regarding the research that has been or is being performed at their old firm. As a result, the benefits to receiving countries depend not only on who migrates there but also on from where they came.

Firms that are seemingly losers with respect to the mover that has left may gain from access to new knowledge. This knowledge may come from the firm that the mover moves to, but also, more generally, from the country the mover moves to. Cockburn and Henderson (1998) compare the culture of “openness” across the research groups of various pharmaceutical firms. To the degree that the mover moves to and from firms with open science cultures, it is not surprising that knowledge flows from the mover’s new location back to their old firm. Inventors are likely to have established social relationships with colleagues at their old firms, which may

persist even after the inventor has moved. The notion that knowledge flows differentially along lines of social relationships is consistent with the evidence presented in Agrawal et al (2003).

It is important to note that although we interpret our findings as offering at least suggestive evidence that labor mobility influences the pattern of knowledge flows, we remain silent on welfare implications. In other words, although knowledge flows to Canada from Wipro in India may increase as a result of a scientist moving from that company to a firm in Canada, the overall welfare implications are ambiguous. Are the new knowledge flows replacing other knowledge flows that would have otherwise occurred in their absence? And if so, are the new knowledge flows higher quality or in some way more valuable than those in the alternate case? We refrain from speculating on this and therefore must be clear that our contribution is to further our understanding of the determinants of knowledge flow patterns, not to comment on the overall welfare implications that result from labor mobility.

Finally, we should not be surprised that Firm Learning from the Diaspora is stronger for movers who move across borders but within the same multi-national firm. If this were not the case, it would imply that firms manage knowledge no better than the market. In fact, the market is strictly disadvantaged in some cases due to non-compete and confidentiality clauses that often restrict the knowledge that movers can share with their new firms. These findings are suggestive of an interesting and important phenomenon. Namely, *how* do movers influence knowledge flow patterns? While we have speculated on how this might occur, sociologists and business scholars have developed reasonably sophisticated theories regarding the types of people and mechanisms that influence these patterns. Our aim is to integrate some of these ideas and theories into more familiar economic models which we can then use to pry inside the black box with further empirical study. We leave this for future research.



## 6 References

- Agrawal, A. and I. Cockburn (2003) "The Anchor Tenant Hypothesis: Exploring the Role of Large, Local, R&D Intensive Firms in Regional Innovation Systems," *International Journal of Industrial Organization*, Vol. 21, pp. 1227-1253.
- Agrawal, A., I. Cockburn, and J. McHale (2003) "Gone But Not Forgotten: Labour Flows, Knowledge Spillovers, and Enduring Social Capital," National Bureau of Economic Research, Working Paper 9950.
- Agrawal, A., D. Kapur, and J. McHale (2005) "Defying Distance: Examining the Influence of the Indian Diaspora on Scientific Knowledge Flows," mimeo, University of Toronto.
- Almeida, P. and Kogut, B. (1999) "Localization of Knowledge and the Mobility of Engineers in Regional Networks," *Management Science*, Vol. 45, No. 7, July, pp. 905-917.
- Audretsch, D.B. and M.P. Feldman (1996) "R&D Spillovers and the Geography of Innovation and Production," *American Economic Review*, Vol. 86 (3), pp. 630-640.
- Cockburn, I., and R. Henderson (1998) "Absorptive Capacity, Coauthoring Behavior, and the Organization of Research in Drug Discovery," *The Journal of Industrial Economics*, Vol. XLVI, No. 2, pp. 157-182.
- Cockburn, I., S. Kortum, and S. Stern, "Are All Patent Examiners Equal? The Impact of Examiner Characteristics on Patent Statistics and Litigation Outcomes," National Bureau of Economic Research WP8980, 2002.
- Dasgupta, P. and P. David (1987) "Information Disclosure and the Economics of Science and Technology." Arrow and the Ascent of Modern Economic Theory, ed. G. Feiwel, New York University Press, New York, NY.
- Dasgupta, P. and P. David (1994) "Towards a New Economics of Science." *Research Policy*, Vol. 23, pp. 487-521.
- Gera, S., S. Laryea, and T. Songsakul (2004) "International Mobility of Skilled Labour: Analytical and Empirical Issues and Research Priorities," Skills Research Initiative HRDC/IC/SSHRC Working Paper Series (D-01).
- Greene, W. (1994) "Accounting for Excess Zeros and Sample Selection in Poisson and Negative Binomial Regression Models." NYU, Department of Economics WP No. EC-94-10, New York, NY.
- Harris, R. G. (2004) "Labour Mobility and the Global Competition for Skills: Dilemmas and Options," Skills Research Initiative HRDC/IC/SSHRC Working Paper Series (D-02).
- Henderson, R. and I. Cockburn (1996) "Scale, Scope, and Spillovers: the Determinants of Research Productivity in Drug Discovery," *RAND Journal of Economics*, Spring, Vol. 27, No. 1, pp. 32-59.
- Jaffe, A. M. Trajtenberg, and R. Henderson (1993) "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations," *Quarterly Journal of Economics*, August, pp. 577-598.

- Jaffe, A., M. Trajtenberg, and M. Fogarty, "The Meaning of Patent Citations: Report on the NBER/Case-Western Reserve Survey of Patentees" in *Patents, Citations, and Innovations*, Adam B. Jaffe and Manuel Trajtenberg, eds., (Cambridge, MA: MIT Press, 2002).
- Jaffe, A.M. and M. Trajtenberg (2002) Patents, Citations, and Innovations: A Window on the Knowledge Economy, The MIT Press: Cambridge, MA.
- Krugman, P. (1991) Geography and Trade, The MIT Press: Cambridge, MA.
- Romer, P. M. (1986) "Increasing Returns and Long Run Growth," *Journal of Political Economy*, Vol. 94, pp. 1001-1037.
- Romer, P. M. (1990) "Endogenous Technological Change," *Journal of Political Economy*, Vol. 98, Supplement to No. 5, pp. s71-102.
- Singh, J. (2005) "Collaborative Networks as Determinants of Knowledge Diffusion Patterns." *Management Science*, 51(5), pp. 756-770.
- Song, J., P. Almeida, and G. Wu (2003) "Learning-By-Hiring: When is Mobility More Likely to Facilitate Interfirm Knowledge Transfer?" *Management Science*, 49(4), 351–365.
- Thompson, P. and M. Fox-Kean (2005) "Patent Citations and the Geography of Knowledge Spillovers: A Reassessment," *American Economic Review*, 95(1), pp. 450-460
- Wooldridge, J. M. (2002) Econometrics Analysis of Cross Section and Panel Data, The MIT Press: Cambridge, MA.
- Zucker, L., M. Darby, and M. Brewer (1998) "Intellectual Capital and the Birth of U.S. Biotechnology Enterprises," *American Economic Review*, 88(1), pp. 290-306.

Table 1: Worldwide Movers																												
		TO																										
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	Total Outflow
FROM	1 Austria	x	8	0	0	2	0	20	0	0	0	0	1	0	0	0	0	0	0	0	0	5	0	0	0	0	0	36
	2 Australia	8	x	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	15	0	24
	3 Belgium	0	0	x	0	1	0	22	1	0	0	8	0	0	0	0	0	0	1	0	0	9	0	0	0	15	0	57
	4 Canada	0	1	1	x	1	0	3	0	0	0	5	3	0	0	0	1	0	2	2	0	0	1	0	0	113	0	133
	5 Switzerland	2	1	2	3	x	1	73	0	0	0	6	7	0	0	0	0	0	10	1	0	14	9	0	0	23	0	152
	6 China	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7 Germany	53	5	58	17	119	1	x	9	13	1	50	43	5	2	5	0	6	21	79	8	20	1	7	4	199	0	726
	8 Denmark	0	0	1	0	0	0	3	x	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3	0	9
	9 Spain	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	8
	10 Finland	0	0	0	0	0	0	0	3	0	x	1	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	8
	11 France	0	2	8	6	8	0	20	1	4	0	x	13	0	0	0	2	0	2	16	0	13	0	0	0	103	0	198
	12 Great Britain	1	11	8	14	6	0	10	0	0	0	39	x	1	0	10	1	0	3	3	1	9	0	2	1	272	0	392
	13 Hong Kong	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0	1	0	0	0	0	0	0	0	0	1	0	2
	14 Hungary	0	0	0	0	0	0	1	0	0	0	3	3	0	x	0	1	0	1	0	0	0	0	0	0	11	0	20
	15 Ireland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0
	16 Israel	0	0	0	0	2	0	2	0	0	0	2	0	0	0	2	x	0	0	0	0	0	0	0	0	46	0	54
	17 India	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0	0	0	0
	18 Italy	0	0	0	0	9	0	7	0	0	0	2	0	1	0	0	0	0	x	2	0	0	0	0	0	11	0	32
	19 Japan	2	7	16	19	6	2	48	0	0	0	19	67	8	0	5	1	1	4	x	13	17	1	6	7	714	0	963
	20 Rep. of Korea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0
	21 Netherlands	10	2	48	3	0	5	3	0	2	0	18	21	4	0	1	0	0	1	4	0	x	0	3	2	9	0	136
	22 Sweden	0	0	0	3	3	0	3	0	2	0	4	1	0	0	0	0	0	1	4	0	2	x	0	0	25	0	48
	23 Singapore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	1	0	1
	24 Taiwan	0	0	0	0	0	5	0	0	0	0	0	1	0	0	0	0	0	0	5	0	0	0	0	x	12	0	23
	25 United States	7	54	58	204	81	18	253	6	29	2	125	228	19	5	14	145	50	60	392	85	106	15	53	180	x	1	2190
	26 Yugoslavia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0
Total Inventor Inflow		83	91	200	269	238	32	468	20	50	3	282	391	38	7	37	152	57	106	508	107	195	31	71	194	1581	1	5212
Total Inventor Outflow		36	24	57	133	152	0	726	9	8	8	198	392	2	20	0	54	0	32	963	0	136	48	1	23	2190	0	5212
Inflow + Outflow		119	115	257	402	390	32	1194	29	58	11	480	783	40	27	37	206	57	138	1471	107	331	79	72	217	3771	1	10424
Ratio		2.31	3.79	3.51	2.02	1.57	0.00	0.64	2.22	6.25	0.38	1.42	1.00	19.00	0.35	0.00	2.81	0.00	3.31	0.53	0.00	1.43	0.65	71.00	8.43	0.72	0.00	
Note: Countries with ratios greater than 1 are net importers of inventors																												

**Table 2: Movers Leaving Canada**

<b>Origin Company Name</b>	<b>Mover Count</b>	<b>Destination Country</b>
XEROX CORPORATION	16	United States
MINNESOTA MINING AND MANUFACTURING COMPANY	14	United States
INTERNATIONAL BUSINESS MACHINES CORPORATION	10	United States
ALBERTA RESEARCH COUNCIL	9	United States
THE GOVERNORS OF THE UNIVERSITY OF ALBERTA	6	United States
MOTOROLA INCORPORATED	6	United States
UNIVERSITY OF SASKATCHEWAN	5	United States
HUSKY INJECTION MOLDING SYSTEMS LTD	4	United States
THE DOW CHEMICAL COMPANY	4	United States
GENERAL ELECTRIC COMPANY	4	United States
QUEENS UNIVERSITY AT KINGSTON	3	United States
ATOMIC ENERGY OF CANADA LIMITED	3	United States
HYDRO QUEBEC	3	United States
WARNER LAMBERT COMPANY	3	United States
BLACK & DECKER INC	3	United States
LABATT BREWING COMPANY LIMITED	2	United States
GENERAL MOTORS CORPORATION	2	United States
UNIVERSITE DE SHERBROOKE	2	United States
HOFFMANN LA ROCHE INC	2	France
THE HOSPITAL FOR SICK CHILDREN	2	United States
THE PROCTER & GAMBLE COMPANY	2	Italy
INCO LIMITED	2	United States
HYDRO QUEBEC	2	France
FORD MOTOR COMPANY	2	United States
E I DU PONT DE NEMOURS AND COMPANY	2	United States
HUSKY INJECTION MOLDING SYSTEMS LTD	1	Switzerland
THE GOVERNORS OF THE UNIVERSITY OF ALBERTA	1	United Kingdom
NORTHERN TELECOM LIMITED	1	France
DOMTAR INC	1	United States
PULP AND PAPER RESEARCH INSTITUTE OF CANADA	1	United States
NORTHERN TELECOM LIMITED	1	Japan
CONNAUGHT LABORATORIES LIMITED	1	United Kingdom
INTERNATIONAL BUSINESS MACHINES CORPORATION	1	Federal Republic of Germany
THE PROCTER & GAMBLE COMPANY	1	United States
NORTHERN TELECOM LIMITED	1	Belgium
THE PROCTER & GAMBLE COMPANY	1	Japan
UNIVERSITY OF SASKATCHEWAN	1	Australia
MAGNA INTERNATIONAL INC	1	United States
HYDRO QUEBEC	1	Federal Republic of Germany
HUSKY INJECTION MOLDING SYSTEMS LTD	1	Federal Republic of Germany
THE GOVERNORS OF THE UNIVERSITY OF ALBERTA	1	Sweden
NORTHERN TELECOM LIMITED	1	Israel
CAE MACHINERY LTD	1	United States
INCO LIMITED	1	United Kingdom
MITEL CORPORATION	1	United States
NORTHERN TELECOM LIMITED	1	Poland
<b>Total Moves</b>	<b>134</b>	

**Table 3: Movers Coming to Canada**

*(Firms with more than 2 movers - Approximately Top 25%)*

Origin Company Name	Mover Count	Origin Country
XEROX CORPORATION	10	United States
INTERNATIONAL BUSINESS MACHINES CORPORATION	6	United States
NORTHERN TELECOM LIMITED	6	United States
NORTEL NETWORKS LIMITED	4	United States
MINNESOTA MINING AND MANUFACTURING COMPANY	3	United States
AMERICAN HOME PRODUCTS CORPORATION	3	United States
APPLIED MATERIALS INC	3	United States
FUJI XEROX CO LTD	3	Japan
DEGUSSA AKTIENGESELLSCHAFT	3	Federal Republic of Germany
NATIONAL RESEARCH COUNCIL OF CANADA	3	United States
HER MAJESTY THE QUEEN IN RIGHT OF CANADA	3	United States
THE UNIVERSITY OF BRITISH COLUMBIA	2	United States
POLYSAR RUBBER CORP	2	United States
MOTOROLA INCORPORATED	2	United States
UNIVERSITY OF AKRON	2	United States
MERCK FROSST CANADA & CO	2	United States
CONCORD CAMERA CORP	2	United States
EXXON CHEMICAL PATENTS INC	2	United States
EXXON RESEARCH AND ENGINEERING COMPANY	2	United States
HYAL PHARMACEUTICAL CORPORATION	2	United States
CORNEL RESEARCH FOUNDATION INC	2	United States
MASSACHUSETTS INSTITUTE OF TECHNOLOGY	2	United States
TEXAS INSTRUMENTS INC	2	United States
PANAVISION INC	2	United States
WISCONSIN ALUMNI RESEARCH FOUNDATION	2	United States
TELEFONAKTIEBOLAGET LM ERICSSON	2	Sweden
HOFFMANN LA ROCHE INC	2	Switzerland
MOBIL OIL CORPORATION	2	United States
PI MEDICAL CORPORATION	2	United States
REGENTS OF THE UNIVERSITY OF MINNESOTA	2	United States
GENERAL ELECTRIC COMPANY	2	United States
POLYSAR CORPORATION	2	United States
KYOWA HAKKO KOGYO CO LTD	2	Japan
HABLEY MEDICAL TECHNOLOGY CORPORATION	2	United States
BRIER TECHNOLOGY INC	2	United States
PACIFIC MONOLITHICS	2	United States
ALLIED CORPORATION	2	United States
SYNNYBROOK HEALTH SCIENCE CENTER	2	United States
ALLIED SIGNAL INC	2	United States
ALFRED E MANN FOUNDATION FOR SCIENTIFIC RESEARCH	2	United States
ADVANCED ENERGY TECHNOLOGIES INCORPORATED	2	Japan
WEATHERFORD/LAMB INC	2	United States
QUEENS UNIVERSITY AT KINGSTON	2	United States
SUNNYBROOK HEALTH SCIENCE CENTRE	2	United States
SIBERCORE TECHNOLOGIES INC	2	United States
BENOPCON INC	2	United States
<b>Total Moves from Sample (From Total of 269)</b>	<b>117</b>	

Table 4: Worldwide Citations																												
		TO																										
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	Total Inflow
F R O M	1 Austria	x	162	43	280	561	4	2720	49	22	133	712	481	10	13	9	36	1	389	3151	54	132	295	2	47	8530	4	17840
	2 Australia	204	x	63	1174	487	2	3040	88	30	237	1142	1125	55	34	21	111	5	391	5126	109	274	506	17	117	27346	3	41707
	3 Belgium	41	61	x	307	388	8	1818	40	17	45	743	602	12	14	17	73	3	258	5452	48	198	165	4	41	12494	0	22849
	4 Canada	362	939	471	x	2216	45	9861	377	104	1082	5151	5306	197	104	114	730	8	1906	26658	844	1178	2966	31	563	134912	14	196139
	5 Switzerland	449	362	370	1356	x	15	11557	460	128	361	3823	2792	243	92	76	230	17	1855	18426	248	986	1991	21	286	65929	6	112079
	6 China	6	13	3	99	89	x	329	10	8	29	271	126	281	4	7	19	2	83	1405	130	63	37	5	199	4168	1	7387
	7 Germany	2020	1549	1579	6136	11241	117	x	1213	419	2859	19594	15328	350	344	194	1082	29	6959	125162	2067	3505	5898	126	1766	297089	28	506654
	8 Denmark	64	73	35	297	382	3	1673	x	16	103	586	561	25	26	7	75	21	170	2282	55	273	275	3	33	11534	0	18572
	9 Spain	27	56	24	150	163	0	850	35	x	29	361	251	18	11	6	46	0	182	1195	34	74	94	1	30	4723	7	8367
	10 Finland	110	160	88	1357	696	41	3780	133	20	x	1189	1750	133	35	6	84	2	323	8440	673	354	2488	10	555	28869	3	51299
	11 France	590	728	633	3064	3644	52	18868	397	266	725	x	6125	185	173	121	470	20	2999	36615	1109	1586	1971	42	585	131148	27	212143
	12 Great Britain	344	806	539	2995	2637	25	15636	458	136	457	6729	x	214	125	119	476	11	1713	28587	492	1197	1882	28	301	123632	10	189549
	13 Hong Kong	20	57	12	372	229	72	694	21	48	49	457	334	x	9	1	52	1	1533	3509	158	88	89	12	399	10475	1	18692
	14 Hungary	7	10	19	40	78	0	274	6	8	11	129	97	0	x	0	15	8	45	361	3	25	31	0	0	1534	7	2708
	15 Ireland	10	39	16	146	125	2	414	50	9	9	145	195	6	8	x	69	1	95	956	20	35	97	1	26	5284	0	7758
	16 Israel	44	176	117	803	544	13	2218	60	11	164	1095	1000	48	39	33	x	1	343	7670	268	237	494	21	435	31579	4	47417
	17 India	29	16	12	52	96	10	223	21	15	15	153	177	1	12	17	21	x	71	650	39	46	26	0	14	2566	1	4283
	18 Italy	397	204	279	1089	1961	28	8410	178	133	186	3302	2046	100	99	33	184	8	x	15729	537	637	718	32	585	45080	4	81959
	19 Japan	2463	2829	4258	16658	15824	430	115125	1667	619	3762	38277	31255	1782	614	375	2855	71	13680	x	25364	7013	10491	752	13216	991699	61	1301140
	20 Rep. of Korea	90	182	190	1741	553	76	4417	110	53	819	2212	1730	148	25	30	226	12	1155	69632	x	517	1021	296	4724	81098	2	171059
	21 Netherlands	155	251	267	1090	1175	20	5409	218	43	368	2106	1722	107	51	21	197	13	830	14768	666	x	760	48	414	50495	2	81196
	22 Sweden	196	377	243	2346	1879	18	7377	234	41	1629	2607	2439	63	82	41	456	5	780	15813	429	849	x	18	226	59110	8	97266
	23 Singapore	3	17	7	95	73	4	272	6	9	29	163	176	23	0	5	30	0	57	2340	379	47	39	x	1107	7320	0	12201
	24 Taiwan	66	172	100	1274	565	187	3608	53	55	535	1621	972	396	15	37	215	4	987	33379	5983	288	455	787	x	74673	8	126435
	25 United States	10513	25463	15218	129698	82111	1580	419954	14225	3860	21412	186790	178235	7887	3866	3886	21301	578	57190	1381372	42863	42274	63877	3911	43238	x	261	2761563
	26 Yugoslavia	1	3	0	5	10	0	14	0	1	1	14	5	1	1	0	3	0	7	36	0	1	2	0	0	108	x	213
Total Knowledge Out flow		18211	34705	24586	172624	127727	2752	638541	20109	6071	35049	279372	254830	12285	5796	5176	29056	821	94001	1808714	82572	61877	96668	6168	68907	2211395	462	6098475
Total Knowide Inflow		17840	41707	22849	196139	112079	7387	506654	18572	8367	51299	212143	189549	18692	2708	7758	47417	4283	81959	1301140	171059	81196	97266	12201	126435	2761563	213	6098475
Inflow + Outflow		36051	76412	47435	368763	239806	10139	1145195	38681	14438	86348	491515	444379	30977	8504	12934	76473	5104	175960	3109854	253631	143073	193934	18369	195342	4972958	675	12196950
Ratio		0.98	1.20	0.93	1.14	0.88	2.68	0.79	0.92	1.38	1.46	0.76	0.74	1.52	0.47	1.50	1.63	5.22	0.87	0.72	2.07	1.31	1.01	1.98	1.83	1.25	0.46	
Note: Countries with Ratios greater than 1 are net importers of knowledge																												

**Table 5: Descriptive Statistics**

<b>Firm Level Data</b>	<b>Obs</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>Min</b>	<b>Max</b>	
Patenting Flow of Firm 1 (1,000s)	45,234	0.103	0.252	0	3.455	
Patenting Flow of Firm 2 (1,000s)	45,234	0.022	0.121	0	3.455	
Patent Stock of Firm 1 (1,000s)	45,234	1.194	2.669	0.001	28.844	
Patent Stock of Firm 2 (1,000s)	45,234	0.263	1.384	0	28.844	
Patent Stock of Firms 2 (1,000s) <sup>†</sup>	45,234	0.589	2.522	0	90.958	
<b>Country Level Data</b>						
Patenting Flow of Country 1 (1,000s)	45,234	28.743	25.785	0	86.084	
Patenting Flow of Country 2 (1,000s)	45,234	12.749	21.453	0	86.084	
Patent Stock of Country 1 (1,000s)	45,234	338.430	338.047	0.015	1229.578	
Patent Stock of Country 2 (1,000s)	45,234	150.135	270.502	0	1229.578	
<b>Dyad Level Data</b>						
Citations by Firm 1 to Country 2	45,234	19.394	121.192	0	5442	
Citations by Country 2 to Firm 1	45,234	23.481	125.828	0	4808	
Citations by Firm 1 to Firms 2 <sup>†</sup>	45,234	1.322	23.411	0	2055	
Citations by Firms 2 to Firm 1 <sup>†</sup>	45,234	1.448	20.524	0	1487	
Citations by Firm 1 to Mover	45,234	0.032	0.539	0	42	
Citations by Mover to Firm 1	45,234	0.109	2.981	0	569	
Citations by Firm 1 to Firm 2 <sup>††</sup>	45,234	0.508	4.419	0	371	
Citations by Firm 2 to Firm 1	45,234	0.527	4.412	0	371	
Citations by Firm 1 to Mover at Firm 2	45,234	0.023	0.439	0	42	
Citations by Mover at Firm 2 to Firm 1	45,234	0.079	2.685	0	514	
Movers from Firm 1 to Country 2	45,234	0.807	1.889	0	47	
Movers from Country 2 to Firm 1	45,234	0.561	2.015	0	49	
Movers from Firm 1 to Firm 2	45,234	0.379	1.135	0	28	
Movers from Firm 2 to Firm 1	45,234	0.277	1.181	0	36	
Technology Overlap between Firm 1 and Country 2	44,823	0.491	0.235	0	0.981	
Technology Overlap between Firm 1 and Firm 2	24,040	0.592	0.291	0	1	
<sup>†</sup> Often dyads contain more than one mover. Consequently, these movers may move to multiple firms. Firms 2 refers to this set of firms.						
<sup>††</sup> This refers to the case where Firm 1 and Firm 2 reflect different offices within the same multi-national firm.						

**Table 6: National Learning by Immigration: Conditional Fixed Effects Negative Binomial Regressions, 1980-2000**

Table 6: National Learning by Immigration: Conditional Fixed Effects Negative Binomial Regressions, 1980-2000									
Dependent Variable	<i>Knowledge Flows from Firm 1 to Country 2</i>								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
									ZINB
Movers to Country	0.0403	0.0418	0.0450	0.0388	0.0450	0.0280	0.2124	0.1696	
	(0.0018)***	(0.0018)***	(0.0017)***	(0.0017)***	(0.0017)***	(0.0019)***	(0.0101)***	(0.0066)***	
Movers to Firm 1						0.0546	0.0637	0.0224	
						(0.0029)***	(0.0106)***	(0.0065)***	
Patent Stock Firm 1	0.1202	0.1191	0.1246	0.1222	0.1257	0.1194	0.2340	0.1630	
	(0.0018)***	(0.0018)***	(0.0018)***	(0.0018)***	(0.0018)***	(0.0018)***	(0.0060)***	(0.0037)***	
Cites by Mover to Firm 1		0.0018			0.0020	0.0020	0.0459	0.0160	
		(0.0003)***			(0.0002)***	(0.0002)***	(0.0132)***	(0.0068)***	
Cites by Firms 2 <sup>†</sup> to Firm 1			-0.0012		-0.0012	-0.0019	0.0384	0.0214	
			(0.0001)***		(0.0001)***	(0.0001)***	(0.0021)***	(0.0010)***	
Technology Overlap				0.9654	0.9586	0.9743	1.5457	0.5803	
				(0.0378)***	(0.0378)***	(0.0379)***	(0.0516)***	(0.0437)***	
Constant	-0.0945	-0.0937	-0.9606	-0.5864	-0.5837	-0.5896	1.4337	2.5013	
	(0.0110)***	(0.0110)***	(0.0111)***	(0.0229)***	(0.0229)***	(0.0230)***	(0.0545)***	(0.0419)***	
Observations	39,280	39,280	39,280	39,086	39,086	39,086	42,736	42,736	
Dyad Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	No	No	
Year Effects	No	No	No	No	No	No	Yes	Yes	
Number of Groups	1964	1964	1964	1964	1964	1964			
Log Likelihood	-90,428.92	-90,415.50	-90,255.44	-89,939.09	-89,851.56	-89,694.31	-124,011.74	-103,086.60	
Chi <sup>2</sup>	15,565.50	15,638.46	15,828.24	16,435.18	16,752.74	16,860.93	12,652.45	11,712.82	
Prob > Chi <sup>2</sup>	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
<sup>†</sup> Often dyads contain more than one mover. Consequently, these movers may move to multiple firms. Firms 2 refers to this set of firms. Note: Standard errors in parentheses *** significant at 1% level									



**Table 7: Learning From the Diaspora: Conditional Fixed Effects Negative Binomial Regressions, 1980-2000**

Dependent Variable	Knowledge Flows from Country 2 to Firm 1				Knowledge Flows from Firms 2 to Firm 1 <sup>†</sup>			
	(1)	(2)	(3)	(4) ZINB	(5)	(6)	(7)	(8) ZINB
Movers to Country 2	0.0175 (0.0022)***	0.0244 (0.0021)***	0.0151 (0.0026)***	0.0199 (0.0052)***	0.0485 (0.0040)***	0.0463 (0.0040)***	0.0385 (0.0048)***	0.0418 (0.0066)***
Movers to Firm 1			0.0209 (0.0032)***	0.0418 (0.0052)***			0.0166 (0.0052)***	0.0359 (0.0050)***
Patenting Flow Firm 1	1.2130 (0.0151)***	1.3020 (0.0153)***	1.2812 (0.0157)***	3.2518 (0.0434)***	0.8841 (0.0347)***	0.9039 (0.0347)***	0.8898 (0.0349)***	0.7499 (0.0401)***
Patent Stock Country 2	0.0008 (0.0000)***	0.0008 (0.0000)***	0.0008 (0.0000)***	0.0026 (0.0000)***				
Patent Stock Firms 2 <sup>†</sup>					0.0127 (0.0026)***	0.0124 (0.0026)***	0.0094 (0.0028)***	0.1010 (0.0031)***
Cites by Firm 1 to Mover		0.0407 (0.0047)***	0.0372 (0.0047)***	0.0834 (0.0135)***	0.0545 (0.0056)***	0.0528 (0.0056)***	0.0506 (0.0057)***	0.1019 (0.0137)***
Cites by Firm 1 To Firms 2 <sup>†</sup>		-0.0009 (0.0001)***	-0.0011 (0.0001)***	0.0133 (0.0008)***				
Technology Overlap		1.1435 (0.0413)***	1.1498 (0.0413)***	0.8419 (0.0378)***		0.9772 (0.1021)***	0.9741 (0.1023)***	0.8820 (0.0778)***
Constant	-0.3892 (0.0127)***	-0.9793 (0.0258)***	-0.9836 (0.0258)***	1.2203 (0.0476)***	-0.9629 (0.0284)***	-1.4358 (0.0584)***	-1.4348 (0.0594)***	0.4393 (0.1270)***
Observations	37,680	37,465	37,465	42,736	15,300	15,225	15,225	42,736
Dyad Fixed Effects	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Year Effects	No	No	No	Yes	No	No	No	Yes
Number of Groups	1884	1884	1884		765	765	765	
Log Likelihood	-82,752.89	-82,089.78	-82,070.48	-88,098.34	-15,008.03	-14,930.62	-14,925.88	-13,371.29
Chi <sup>2</sup>	10,873.39	11,345.19	11,425.57	17,900.81	3,281.66	3,400.38	3,394.24	4,079.09
Prob > Chi <sup>2</sup>	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

<sup>†</sup> Often dyads contain more than one mover. Consequently, these movers may move to multiple firms. Firms 2 refers to this set of firms.

Note: Standard errors in parentheses

\*\*\* significant at 1% level

**Table 8: Intra-firm Learning From The Diaspora:  
Conditional Fixed Effects Negative Binomial Regressions, 1980-2000**

Dependent Variable	<i>Knowledge Flows from Firm 2 to Firm 1</i>				
	(1)	(2)	(3)	(4)	(5) ZINB
Movers to Firm 2	0.1211 (0.0071)***	0.1245 (0.0071)***	0.1052 (0.0075)***	0.0885 (0.0092)***	0.0701 (0.0117)***
Movers to Firm 1				0.0269 (0.0080)***	0.1011 (0.0116)***
Patenting Flow Firm 1	1.1457 (0.0379)***	1.1397 (0.0378)***	1.0425 (0.0416)***	1.0271 (0.0412)***	0.4635 (0.0395)***
Patent Stock Firm 2	0.0837 (0.0058)***	0.0809 (0.0059)***	0.0730 (0.0060)***	0.0675 (0.0063)***	0.0934 (0.0055)***
Cites by Firm 1 to Mover		0.0556 (0.0052)***	0.0522 (0.0056)***	0.0536 (0.0056)***	0.1141 (0.0154)***
Technology Overlap			1.5673 (0.1085)***	1.5397 (0.1087)***	0.6793 (0.0892)***
Constant	-1.1797 (0.0346)***	-1.1767 (0.0348)***	-2.1141 (0.0834)***	-2.0948 (0.0835)***	0.3151 (0.1464)***
Observations	13,280	13,280	11,184	11,184	23,444
Dyad Fixed Effects	Yes	Yes	Yes	Yes	No
Year Effects	No	No	No	No	Yes
Number of Groups	664	664	654	654	
Log Likelihood	-11,187.27	-11,155.27	-10,599.86	-10,594.50	-9,448.65
Chi <sup>2</sup>	2,228.57	2,384.70	2,055.91	2,082.62	1,620.38
Prob > Chi <sup>2</sup>	0.0000	0.0000	0.0000	0.0000	0.0000
Note: Standard errors in parentheses					
*** significant at 1% level					