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FEATURE ARTICLE 2

AGGREGATION, INTEGRATION AND PRODUCTIVITY ANALYSIS: AN OVERALL FRAMEWORK

BY
René Durand

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FEATURE ARTICLE 2

Aggregation, Integration and Productivity Analysis: An Overall Framework

By René Durand[27]

1 - Introduction

Vertical integration of production activities within the firm usually refers to its internal allocation of resources. Firms integrate vertically when they produce part of their own commodity inputs instead of buying these on the market. For instance, an automobile firm might buy a steel plant and produce its own steel instead of buying steel from a steel company. The internal allocation of resources of firms through vertical integration can be contrasted to the market allocation of resources between firms through exchange of goods and services. The more productive resources are allocated by the firms themselves through their internal organization, the less firms are interdependent for the purchase of their material and service inputs and the sale of their output. Therefore, vertical integration and market interdependence can be seen as the two opposite sides of the same coin. But clearly, production processes remain interdependent whether they are integrated by the firms or through exchanges of goods and services on the markets. Production processes transform primary inputs of capital and labour into intermediate inputs (raw materials and services) which are, in turn, transformed into other goods and services and so on up to their ultimate use, that is, in the jargon of the national accountants, up to their deliveries to final demand.

However, our perception of the production processes and, in particular, of productivity growth associated with the evolution of these processes through time, is greatly influenced by vertical integration as will be seen below. Vertical integration can be real as defined above or artificially created by transforming the data so as to "statistically" integrate the production process. Real vertical integration within the industry occurs when establishments, which previously exchanged goods and services, merge together. The transactions which were occurring between these establishments disappear from the statistical records as transactions are only reported at the establishment level. Similarly, statistical integration can be performed by not accounting for transactions between establishments as if they were integrated.

Aggregation of production activities refers to the transformation activities of a group of establishments. This group may be the industry at various SIC digit code level or the whole business sector. Aggregation can be performed by adding up, commodity by commodity, the input and output data of establishments. Alternatively, aggregated production data can be computed so as to exclude intraindustry sales, that is the sales of establishments to other establishments of the same industry. Aggregated activities of

[27] *The author wishes to thank Ian Stewart and Terri Markle for their valuable comments on an earlier draft of this paper. The author nevertheless remains solely responsible for errors and omissions.*

establishments may be integrated for analytical purposes by not taking into account the flows of goods and services between them as if these flows were internal to the establishments or equivalently, as if all establishments of the industry were merged into a single large establishment for which we would observe only the flows of inputs coming in and the flows of outputs coming out. In that case, it consists in a partial integration within the industry. Statistical integration may be extended to include interindustry transactions on commodity inputs as well. But, as will be seen below, integration can also be done without aggregation. Therefore, not only does real vertical integration have an impact on the measure of inputs and outputs of production activities but so does the manner in which the statistician or the economist computes inputs and outputs, particularly when aggregating over establishments within in an industry or industries within the economy. It may involve further integration (though not necessarily) of production processes. In changing the measure of inputs and outputs of production processes, integration significantly affects productivity measurement.

That vertical integration and aggregation are two distinct and independent dimensions of productivity analysis is one of the most important notion which is discussed in this article. Productivity can be measured without statistically integrating production activities vertically nor is such integration limited only to cases when aggregation is performed. Aggregation can be performed without integration and vice versa.

Once the above distinctions related to integration and aggregation are recognized, a general analytical framework follows that encompasses most productivity models that appear in the literature. This framework provides a powerful tool to clarify issues and debates about the advantages and weaknesses of alternative productivity models. This will be illustrated by the many examples which will be presented in the article. The framework also lays a better foundation for all of the productivity models presented in this publication as well as other models still in development which are also briefly described in this article.

Rymes[28]'interindustry model is first contrasted with the traditional neoclassical productivity model at the industry level of aggregation. The analytical framework provides support to intuition in understanding the aggregation weights for industries' productivity indices to the aggregate business sector level. In particular, it helps understanding why the aggregation weights of the neoclassical industry productivity indices add to more than one or, what amounts to the same, why aggregate productivity is larger than the average of individual industries' productivity.

The choice of the appropriate gross output measure at the industry level, that is gross output net or not of intraindustry sales, is discussed next. The choice between the value added and the gross output concept is clarified in the following section where the value added model is also compared with the final demand commodity model and the interindustry model. Gollop's[29] (1982) model of an open economy is examined next and compared to the traditional view which measures aggregate productivity on the basis of real value added. It provides the framework to assess the merits of the alternatives of including or not imports into the set of primary inputs for an open economy.

Integration proceeds by linking productive processes across establishments, industries or economies on the basis of their exchange of input commodities. These include all intermediate inputs and, at the international level, imported commodities used as inputs. Imports are often classified as primary commodities in economic analysis. These commodities all share the property of being produced commodities as opposed

[28] *See Rymes T.K. and Cas. A., "On the Feasibility of Measuring Multifactor Productivity in Canada", Input-Output Division, Statistics Canada, Winter 1985.*

[29] *Gollop, F.M., "Growth Accounting in an Open Economy" in A. Dogramaci (ed.) Developments in Econometric Analysis of Productivity, Measurement and Modelling Issues, Kluwer Nijhoff Pub., Boston, The Hague, London, 1982.*

to capital and labour. But capital goods, although they are accumulated over many periods, are also produced commodities over which, consequently, it would appear reasonable to integrate production processes. However, such an integration cannot be done within the *static* production framework. Integration over capital goods can only be done through time by extending the analytical framework to cover many periods. This leads us to introduce and discuss a last productivity model with its corresponding dynamic productivity index number formula.

2- The Impact of Integration on Productivity Measurement

In general, vertical integration increases measured productivity growth. As interdependent activities reinforce one another, their joint productivity, when integrated, is higher than the average productivity of the isolated activities. This can be seen as follows. When an establishment uses inputs from other establishments of its industry it is, from the integrated group's perspective, as if it were using indirectly the inputs of its suppliers. It therefore incorporates the productivity gains made on the *production* of these inputs (now being assumed to be own production) with those made on its own *use* of these inputs. Integrating the activities of establishments within an industry, that is, taking into account their interdependence, yields a larger estimate of the industry's productivity gain then simply averaging its establishments' productivity gains.

From another perspective, integration can be seen as transforming the inputs of the production process. Intermediate inputs (purchased raw materials and services) of a production process are replaced by the inputs used to produce them. With further integration, the latter inputs may, in turn, be replaced by the inputs of the supplying industries and so on. In the process, *intermediate* inputs, that is *produced* inputs, are replaced by both other intermediate inputs and some *primary*, that is by *non-produced,* inputs. Full integration (both within and across industries) means that all produced inputs are transformed into primary inputs by linking all production processes together and looking only at what goes in and what comes out of the whole set of processes as if all of them were carried out by a single establishment. As primary inputs generally grow at a smaller rate than intermediate inputs because of the productivity gains which are made on the production of the latter, substitution of primary inputs for intermediate inputs lead to higher productivity growth estimates.

In the appraisal of productivity gains, whether and to what degree interdependence should be taken into account must be determined by the purpose of the analysis. Productivity is a relative concept, not an absolute concept, which depends on the perspective of the analyst. The productivity of an industry, for instance, is not a completely defined concept, the reason being that it may be considered from different perspectives, ranging from the perspective of its establishments as components of the industry to the perspective of the industry as an integrated component of the aggregate economy. The appropriate perspective to be taken depends on the degree to which the integration (interdependence) of the productive activities to wider economic activities is deemed analytically important. Some phenomena can only be explained with the proper integration perspective as shown below. The degree of integration is not just a matter of taste.

For example, from an economy wide integration perspective, that is taking into account all interindustry transactions, an industry uses either *directly or indirectly* (through purchases of goods and services from its suppliers) part of the economy's available inputs of capital and labour to produce some bundle of commodities. From that perspective, the industry is viewed as a fully *integrated* component of the set of business industries. This perspective leads to the *interindustry* index of multifactor productivity discussed in Appendix 1, *Basic Concepts and Methods*, of Part 2 of this publication. From a narrower perspective of

a single industry, it uses capital and labour *plus purchased materials and services* to produce some bundle of goods or services which are sold *directly* to other producers or to final demand markets. The industry is viewed as an isolated (non integrated) economic entity, that is without considering its links to other industries. This is the neoclassical *industry* perspective also developed in Appendix 1. This article further develops and extends these ideas.

3 - The Industry versus the Interindustry Model

Rymes has argued that intermediate inputs, because they are produced inputs, should have a different status than primary inputs. The argument is that since these inputs are themselves outputs of the productive system, they incorporate productivity gains of their originating industries. These productivity gains must be incorporated in the assessment of the productivity of any industry. Neoclassical productivity theory fails to take these gains into account and therefore underestimate productivity growth. This would explain why individual industry productivity gains must be "inflated" to obtain aggregate productivity gains[30].

Rymes' arguments for the interindustry model can be cast in terms of integration. The logic is as follows: when an industry is using intermediate inputs, it is, in fact, indirectly using the inputs of the industries producing these intermediate inputs. But these latter industries are indirectly using the inputs of their upstream suppliers. If we consider all industries simultaneously, it amounts to saying that industries are directly and indirectly buying primary inputs from all upstream industries. Their outputs are therefore related to their own primary inputs and those of their upstream suppliers instead of their own primary and intermediate inputs as in the neoclassical model. Industries are all *vertically integrated*. The perspective or integration level clearly covers all intermediate inputs (all interindustry links) so that production is expressed as a function of the primary inputs of the business sector while the focus is some particular bundle of commodities (gross output) produced by a given industry. The level of integration, which can be characterized by the set of interindustry relationships which are taken into account and which, in the present case, covers all industries of the business sector, differs from the level of aggregation which is the industry. In the neoclassical world, integration is fixed at the establishment level at all levels of aggregation, including the industry level on which attention is presently drawned, except for the total business sector. In the latter case, neoclassicals assume full integration. Thus, the productivity estimates for the interindustry and the industry models differ except at the total business sector level. In general, the interindustry productivity estimates tend to be larger than the neoclassical industry productivity estimates as the rate of growth of primary inputs is smaller than the rate of growth of intermediate inputs. Indeed, if productivity is positive, intermediate inputs, which are also outputs of the productive system, must have a larger rate of growth than the primary inputs used in their production. Again, integrated activities generally show larger productivity gains than the average over the productivity gains of the component activities.

Considering these two models in terms of aggregation, however, the neoclassical model changes perspective when aggregating industries' productivity gains to the total business sector level. Aggregation is effectively done *with* integration of industries. Vertical integration in a statistical sense is implicitly performed when industries' productivity gains are aggregated to the total business sector level using recognized procedures such as those suggested by Domar and Hulten[31]. That is, when productivity gains

[30] *Hulten also proposes the same integrated* ***interindustry*** *measure of productivity at the industry level when he distinguishes between productivity changes* ***originating in*** *a sector and the* ***impact*** *of productivity changes* ***on*** *the sector. See Hulten (1978),"Growth Accounting with Intermediate Inputs", Review of Economic Studies, pp.511-518.*

[31] *Hulten Charles R. op. cit..*

of individual industries are aggregated to the total business sector, something more than averaging their productivity gains is actually taking place. The aggregation rule effectively integrates vertically all establishments into a single large establishment whereby inter-establishments transactions cancel out. Intermediate inputs vanish in the process leaving only primary inputs and, as a counterpart, real value added. This integration process affects substantially the resulting measure of aggregate productivity, as shown on figure 3 of the first feature article, and is the single fundamental factor which explains why aggregate productivity growth is not simply a weighted average of industries' productivity growth. This implicit integration explains why aggregation weights sum to more than one. These weights are the gross outputs of industries (non-integrated measure) into the total value added of the economy (integrated measure). In the interindustry model, the integration level is the total business sector level for both the industry and the business sector. This also explains why aggregation weights sum to one. These weights are the final demand delivery shares of industries into total final demand deliveries. Taking into account only final demand deliveries and the associated primary inputs used directly or indirectly corresponds closely to the production function of final demand commodities.

Both productivity models are useful as it is informative to look at industries' productivity from the perspective of both integration levels. Managers from the industry's establishments may be interested to the neoclassical productivity measure to compare their performance with the average performance of the industry uniquely over the transformation process over which they have some control. On the other hand, an economist interested in the comparative advantage of an economy in the production of some goods at the international level might prefer to look at the productivity of the whole set of production activities involved.

4 - The Choice of Gross Output

Productivity growth is simply defined as the rate of growth of output minus the rate of growth of inputs of some economic unit. Though that is a simple statement, a good deal of controversy on applied productivity analysis focuses on the question of how to correctly define outputs and inputs at various levels of aggregation, from the establishment level to the aggregate economy level. In particular, controversy has occurred on the measurement of an industry's output as either its gross output, its gross output net of intraindustry sales, or its real value added. The latter measure of output has been dismissed by many analysts but, as we shall see below, it may be worthwhile reconsidering.

The controversy between gross output and gross output net of intraindustry sales can be understood again as a question of perspective on integration. Gross output net of intraindustry sales corresponds to the idea of what goes in and out of the industry. It consists in a partial vertical integration of establishments over their sales to other establishments of the same industry. In other words, it uses only within industry interdependence links. Domar[32] (1961), in fact, applies (see his rule II) the net gross output concept to the productivity of any "sector" aggregate such as total manufacturing, not only to the productivity of the total business sector aggregate.

The interindustry model just discussed integrates establishments upstream both within and across industries. The level of integration exceeds the level of aggregation. In the gross output net of intraindustry sales model, the level of aggregation and the level of integration coincide. They are both at the industry level.

[32] *Domar himself was aware of the importance of integration in aggregation as he was looking for an aggregation rule which was invariant the actual degree of integration in the real world. He achieved that result by statically integrating fully all industries together.*

In the gross output framework, these levels differ. Integration is at the establishment level while aggregation is at the industry level.

It may be argued that maintaining both integration and aggregation at the same level is preferable as it provides a "smoother" aggregation rule than in the traditional neoclassical model in which industries' output is taken to be the gross output at any level of aggregation except at the total business sector level. Indeed, the higher the level of aggregation, the more important intraindustry sales are in proportion to total intermediate inputs so that net intermediate inputs gradually and smoothly vanish towards zero when going from disaggregated industry levels to the aggregated business sector level. Net-gross output similarly converges gradually toward value added as aggregation goes. This avoids the difficult abrupt switch from a gross output measure at very aggregated levels, such as total goods industries and total services industries, to value added at the business sector level. This switch has always been felt as uneasy in applied productivity analysis.

As a counter argument, one may argue that, as the integration level changes with aggregation, components cannot be compared to their corresponding aggregates. Aggregate manufacturing industries' productivity gains are larger than the weighted average productivity gains of individual manufacturing industries[33]. Similarly, establishments' productivity gains are smaller, on average, than the productivity gains of the integrated establishments or industry. Integration, indeed, implies, for the reason explained in section 2, that aggregation weights sum to more than one. But, it may well be interesting for comparative analysis of establishments' productivity gains to their industry or industries' productivity gains to their industry group, not to integrate when aggregating. Again, it is all a matter of perspective and this perspective must be chosen by considering the context of the particular issue at hand. Clearly, however, it seems that the larger an aggregate is, the less interesting might be its comparison with its fine components so that net gross output would appear to be a more interesting concept than gross output at high aggregation levels. Net gross output based productivity measures also have the advantage of being less sensitive to real intraindustry integration change through time. On the other hand, comparisons of productivity gains across industries might be better based when on a gross output concept as the importance of intraindustry sales vary across industries. Because of that, net-gross output based productivity measures are so not immediately comparable between industries. From what precedes, one may draw the more general conclusion that productivity measures can only be numerically compared when they refer to the same integration level while aggregation does not affect their comparability.

5 - Value Added versus Gross Output

Value added is often rejected as a measure of output for productivity analysis at the industry level on the ground that, unless some strong separability conditions are met[34], the resulting productivity estimates differ from the "correct" productivity estimates based on the gross output model. This idea, of course, rests on the premise that there exists a uniquely correct absolute value of productivity which is independent of the analytical context. But again, it may be shown that this choice too can be understood in terms of perspective on integration and is much more a matter of analytical purpose. If the integration level which is considered is the establishment level, the correct measure of output is the gross output measure.

[33] *It must be noted here that, in the interindustry model, the productivity estimates remain the same when using the net-gross output rather than the gross output.*

[34] *These conditions basically mean that intermediate inputs and primary inputs form two separate groups of inputs such that intermediate inputs can be subtracted from gross output as in the double deflation method.*

Industries are then looked as groups of establishments operating in isolation from one another. However, in the perspective of their full integration to the business sector level, value added may appear as a valid measure of output at the industry level. Real value added must, however, be measured differently from the usual manner based on the double deflation method[35]. Real value added must be computed as the deflated direct and indirect contributions of an industry to final demand commodities. Each nominal contribution of an industry to a final demand commodity delivery is deflated by that commodity price and the deflated commodity contributions of the industry are aggregated on the basis of the Divisia principle[36].

Industries are seen, in such a perspective, as being integrated together, joining their capital and labour resources to produce final demand commodities. It is thereby describing a quite different production process and consequently, the resulting productivity estimates differ from the neoclassical productivity estimates. In that context, separability appears as a false issue. Indeed, the separability question makes sense only if value added and gross output are conceptually contrasted at the same level of integration as is the case when real value added is measured with the double deflation technique. But value added need not (and should not) be considered as an output measure at the industry integration level because its meaning essentially rests on the industries' direct and indirect contribution to final demand deliveries, that is on a full integration perspective. In the non-integrated perspective, real value added simply does not meaningfully exist and cannot be compared to gross output.

The main advantage of the value added based productivity measures would be their insensitiveness to the "thickness"[37] of the industry that is, to the importance of intermediate inputs in total costs. Industries' productivity measure would all be defined at the same (full) level of integration and would be fully comparable both across industries and through time. Value added based productivity measures are easily computed from the neoclassical measures by multiplying the latter by the ratios of gross output to value added. It can be shown that such an integration rule is quite general: Whenever integration proceeds over some intermediate inputs on both sides of the productivity equation, the integrated productivity measure is always equal to the non-integrated productivity measure multiplied by the ratio of the non-integrated output to the integrated output[38].

As the interindustry productivity measure (defined on gross output) is, similarly to the value added productivity measure, an industry aggregation level productivity measure from a full integration level perspective, it is certainly interesting to investigate the differences between these two measures. The interindustry measure corresponds, in fact, to a group of vertically integrated industries rather than to a single industry while the value added measure corresponds to an individual industry component of that group at the same level of integration. One advantage of the value added based productivity measures is that double counting, which appears in the interindustry measure, is suppressed. Indeed, in the interindustry measure, primary inputs are taken into account both as direct primary inputs in their industry and as indirect primary inputs in the downstream industries. As a consequence, the vertically integrated industry groups overlap and primary inputs are counted many times. For instance, the steel product vertically integrated industry group is also, partly, a component of the automobile vertically integrated industry group. The automobile industry group is using the same primary inputs as the steel industry group to the extent that

[35] *This method consists in deflating the industries' outputs and inputs and subtracting the deflated inputs from the deflated outputs.*

[36] *See Durand, R. "An Alternative to Double Deflation for Measuring Real Industry Value Added", Statistics Canada, Input-Output Division, March 1990.*

[37] *On this, see also Domar (1961), p.726.*

[38] *In the interindustry model discussed above, integration was performed only on the input side while maintaining output fixed so that this rule did not apply.*

the automobile industry is using steel. The industries which are located downstream to the steel industries are using all of the steel industry group primary inputs except if some of the steel is delivered to final demand. It follows that, in order to count the contribution of primary inputs only once, only the vertically integrated industries delivering to final demand must be considered when aggregating. This explains, once more, the aggregation rule in the interindustry model: the aggregation weights are the final demand delivery weights of industries. But productivity gains made on final demand deliveries of industries, in the interindustry model, correspond to productivity gains made on the same final demand commodities in the final demand commodity productivity model[39]. Integration is identical in both models and, as a consequence, both models are identical[40]. They provide productivity measures on commodity outputs whether these outputs are gross or net. It follows that the interindustry and the final demand models should not be drastically opposed as it is sometimes done.

The final demand model is just itself a condensed view of a more general framework expressing productivity gains both by commodity and industry and which corresponds to the deflated industries' contributions by final demand commodity referred to above. The final demand commodity model aggregates productivity gains over industries' contributions corresponding to specific commodities while the value added model aggregates these gains over the commodities' contributions of specific industries. In both cases, aggregation proceeds while the integration level remains fixed at the business sector interdependence level. Aggregated results are therefore identical and aggregation weights sum to one in all those cases. It can be shown, indeed, that these aggregation weights are given by the ratios of commodity value shares in total final demand in one case and industries' value added to the business sector value added, in the other case.

6 - The Closed versus the Open Economy Model

Gollop[41] has advocated that the traditional approach to measure productivity at the aggregate business sector level was incorrect in an open economy. Output of the business sector is not the business sector's value added but its deliveries to final demand. This is equal to final demand net of final demand imports. Materials imported as inputs, correspondingly, enter in the input set jointly with capital and labour. As the integration level is lower than when productivity is defined with respect to real value added, productivity growth is also lower in that model.

Again, Gollop's recommendation is to fix both aggregation and integration at the same level. What must be considered is what goes in and out of the business sector. However, doing so, it can be shown that the productivity gains associated with international economic integration are not taken into account. Gollop's model corresponds to the view that, though open, each economy operates in isolation from one another. To see why, let us consider two economies which are trading in raw materials and service inputs. For the sake of simplicity, let us assume also that these two economies are closed to the rest of the world. In Gollop's model, the aggregate productivity of these two economies is measured on the production process which has, on the output side, the deliveries to the final demand and, on the input side, capital, labour and

[39] *The final demand commodity model expresses the productivity gains on each separate final demand commodity as the difference between the rate of growth of that commodity and the rate of growth of the primary inputs used directly and indirectly in its production.*

[40] *Except for the trivial distinction, in a rectangular input-output framework, that the productivity gain associated with a final demand commodity is a weighted average of the productivity gains of the possibly many industries producing that commodity.*

[41] *Gollop, F.M., op. cit.*

imported inputs. In the alternative traditional view, these same economies are seen as being integrated together. From that higher level of integration perspective, imports now appear simply as intermediate inputs. But at the aggregate level, these intermediate inputs become produced inputs which do not enter into the aggregate production function. The latter is specified only on value added on the output side and, on the input side, on capital and labour. The productivity gains of the integrated economy are therefore generally larger than the weighted average of the productivity gains of the component economies. The aggregation weights, once more, add up to more than one.

From the higher integration perspective, the productivity gains are higher because the benefits from economic integration resulting from trade are taken into account. Those benefits are excluded from Gollop's measure. As, over the long run, real income accruing to primary inputs depends essentially on productivity growth from an integrated perspective, Gollop's model, consequently, could not explain the growth in the real price of capital and labour services[42].

To conclude, once more, both models have their merits. They ask and answer different questions. Their value does not rest on one being better than another but on how well they answer to the question which is at stake and on how relevant that question is.

7 - Integration through Time: A Dynamic Perspective

Capital goods are produced commodities over which industries can be linked. However, industries, in any time period, are not directly providing capital services to one another. Capital services can rather be seen as being provided by asset holders. The latter buy their capital goods (through, say, financial markets) which they accumulate and lend to the firms against a rental income. At the time capital goods are purchased, they are part of capital goods industries' deliveries to final demand. Productivity gains are realised on the production of these capital goods in each period so that their production requires less and less primary inputs as time goes. This simply means that households holding the assets now have to sacrifice less consumption goods (that is to save less) than in the past to obtain the same capital goods. The capital stock, therefore, grows through time both because of savings and because of technical progress in the capital goods producing industries and their upstream suppliers.

It may be argued, from an economic standpoint, that the sacrifice done by households through their savings, and for which they are paid for, is the postponement of their consumption. Households basically supply labour (sacrifice leisure) and postpone their consumption (wait). Technical progress is a free gift of nature and cannot be considered as a production factor. It follows that only that part of the capital stock originating from savings should be considered as an input. The growth of the capital stock resulting from technical progress should be accounted for in the productivity residual.

The amount of consumption forgone per unit of capital is decreasing through time as just mentioned so that the real cumulated value of the waiting sacrifice is growing less rapidly than the cumulated capital stock. In other words, for the same waiting sacrifice, the growth in the capital stock is larger when capital goods

[42] *There is an additional issue in the present case, which is to determine how productivity gains should be shared between the two economies. Business sector final demand deliveries can be distributed on the basis of domestic and foreign factor income. Growth in the production originating from imported inputs uses, measured on the basis of these shares, should exceed, if productivity gains are positive, the growth in the real value of the imported inputs. This difference could be interpreted as being the net gain received by the domestic factors resulting from international trade. Thus, the real gross domestic product would still be the most adequate measure of domestic factor income as in a closed economy.*

producing industries register productivity gains than otherwise. Taking waiting as *the primary input* in place of the capital stock, or integrating over capital goods through time, therefore, leads to larger productivity gains estimates than when using the traditional measure of the capital stock.

The latter, in a time perspective, appears as an intermediate input in that it is the transformation of waiting inputs into capital goods which are themselves totally re-used by industries as inputs to produce consumption goods. Indeed, the capital stock is never consumed and capital goods are not part of final output when considering an infinite time horizon. It may be argued that, over a limited horizon, the capital stock can be looked at as a pure stock of wealth in that it only represents future consumption. It may also be argued along the same lines that, in such a perspective, the capital stock should be deflated by a consumption price index[43]. To complete the picture, waiting services inputs should be measured as the number of some base year units of consumption foregone consumed in the production process, that is as a kind of depreciation of the accumulated stock of waiting[44].

8 - Concluding Remarks

As illustrated by a few examples which, to the exclusion of the dynamic indices, are reproduced on figure 1, the application of the analytical framework into which aggregation and integration are seen as two independent dimensions of productivity analysis, one determining the object of analysis and the other the perspective, can be a powerful tool. But integration is not just a matter of perspective; it is also a matter of fact. Industries are integrated (that is interdependent) components of the business sector of any economy as well as the latter is an integrated component of productive economies at the international level. Some facts can only be explained by models into which integration as a perspective correspond to integration in the real world. We have raised such a point with respect to the analysis of the prices of capital and labour services when discussing the merits of Gollop's open economy versus the "closed" economy model.

Rymes had raised a similar issue with respect to the prices of intermediate inputs. How can it be, he was arguing, that intermediate input prices do not grow faster than output prices as a result of productivity gains? According to the neoclassical view, indeed, input prices must grow faster than output prices if productivity is growing. This is, in fact, simply the dual expression for productivity growth measurement. But this is paradoxical as intermediate inputs are also outputs of the same productive system and must have the same prices as outputs. Rymes concludes from that paradox that the neoclassical productivity model must have something wrong. Of course, this is just a matter of perspective again. But clearly, only the perspective of full integration is capable of explaining the paradox. That is, prices can be explained only into a general equilibrium framework into which interdependence are taken into account, not into the partial equilibrium isolated industry model.

[43] *For a more detailed discussion, see Durand R., "Growth accounting and the quality adjustment of the capital stock", Statistics Canada, Input-Output Division, February 1990.*

[44] *Capital services are usually assumed to be proportional to the stock of capital which is equivalent to assume that they are equivalent to depreciation only when the latter is a fixed proportion of the existing net stock. This happens only when depreciation is geometric.*

Figure 1

Classification of alternative productivity models into the integration-aggregation framework

Integration \ Aggregation	Establishment	Industry	Group of industries	Business sector
Establishment	Neoclassical industry gross output	Neoclassical Industry gross output	Neoclassical Industry gross output	Not used
Industry	Not used	Neoclassical net-gross output	Not used	Not used
Group of industries	Not used	Not used	Neoclassical net-gross output	Not used
Business sector	Not used	Interindustry gross output Industry value added	Interindustry gross output Industry value added	All Models including final demand

Similarly, if balanced growth in the original Solow[45] model was compatible only with Harrod neutral technical progress, it was because productive processes were not integrated through time over capital goods. This fixed the relative price of capital goods with respect to consumption equal to one, leaving no room for technical progress to increase the real price of that input. But the price of waiting can increase similarly to the price of labour through time under the action of technical progress as more capital or consumption units per unit of waiting can be obtained. Only this larger integration perspective can be used to relax the unduly restrictive assumption made by Solow on technical progress.

Finally, it seems that there would be some advantages of using full integration productivity measures at both the industry and aggregate level as integrated measures are free from the changing degree of real integration of establishments through time and as they ease cross-industry comparisons. This would leave

[45] *Solow. R.M., "A Contribution to the Theory of Economic Growth", Quarterly Journal of Economics, LXX, 1 (February,1956), pp. 65-94.*

the interindustry/final demand model and the industry value added model as the preferred choices both cast in terms of the dynamic framework into which integration proceeds over capital goods through time.

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