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Identification of Strategic Industries: A Dynamic Perspective

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Identification of Strategic Industries: A Dynamic Perspective

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ABSTRACT

Every once in while, national or regional governments are faced with decision problems concerning important firms or even whole industries which go into a deep crisis. Reliable estimates of the economy-wide losses are generally hard to obtain. Similarly, governments sometimes would like to get some indication of the potential social benefits associated with attracting an industry which is not yet represented in the country or region. In the input-output literature, with its explicit focus on interindustry analysis, measures of the social value of industries were proposed. These measures are based on comparative statics results, whereas a dynamic perspective seems much more in demand (especially after the new wave of growth theories that emphasize the role of governments in promoting growth). In this paper, "hypothetical extraction" methods as proposed before in a static context are used in a dynamic interindustry model of economic growth, which also stresses the importance of technological linkages between industries. When sufficient data are available, more complete indications of the strategic importance of industries can be given.

* This paper originates from the TEG research project jointly carried out by researchers at the universities of Eindhoven, Groningen and Maastricht (see http://www.tm.tue.nl/ecis/teg/). The paper has benefited from discussions with project group members Erik Dietzenbacher and Bart Verspagen on (sometimes jointly written) related papers. Alessandro Nuvolari and Marcel Timmer offered useful comments and suggestions. The Dutch Organization for Scientific Research is gratefully acknowledged for financial support.

1. Introduction

Every now and then, national and regional governmental bodies are faced with big firms getting into deep crises. Sometimes, the endangered firms are so big that the existence of an entire industry is under threat.[1] In many cases such industries cannot survive without massive public financial support. Governments have to carry out a cost-benefit analysis to decide whether support should be granted or not. Adding to the complexity of this analysis is the fact that industries are generally far from isolated, but are part of different types of networks. Although they only take one type of industry network into account (in which industries are tied to each other by means of intermediate input flows), input-output analysis has been seen as a natural tool for predicting the feedbacks of circumstances in a single industry on the economy as a whole.

This paper aims at extending the techniques currently in existence in at least three respects. First, the proposed technique does not only deal with interindustry commodity flows, but also considers technological interdependencies between industries. Second, the method starts from an explicit dynamic perspective, unlike the existing techniques that focus on comparative statics results. Third, instead of looking at an autarkic country (or disregarding any effects of changing import/export ratios), the proposed technique will explicitly consider current account changes due to the disappearance of an industry as a factor that influences the performance of a country.

The paper is organized as follows. In the next section, a short overview of input-output techniques to measure the importance of industries will be given. Their main disadvantages will pass in review. Section 3 will be devoted to an alternative framework. First, a dynamic input-output model with technological change and balance-of-payments effects will be presented. Next, it will be shown that one of the existing input-output methodologies ('hypothetical extraction') can rather easily be applied to this model, in order to obtain a much more comprehensive indication of the nationwide importance of specific industries. In Section 4, some simulation results will be discussed. Key variables like aggregate consumption, GDP, unemployment rates and the industrial output structure will be discussed. Next, i.e. in Section 5, the extended 'hypothetical extraction' methodology will be used to identify the factors underlying the degree to which an industry is strategic or not. Section 6 concludes by a discussion of the potential usefulness of this approach and the data required to implement the methodology for practical purposes.

2. Interindustry Linkages Measurement : A Brief Survey

An important determinant of the magnitude of effects of changes in one industry on the economy as a whole is the strength of linkages with other industries. The more 'isolated' an industry, the more the economy-wide effects will remain limited to itself. For a long time, it seemed that the only type of linkages which were of interest to economists were the ones based on interindustry trade. Many of these linkages can well be derived from input-output

[1] See, for example, the downfall of the only Dutch aircraft manufacturer, Fokker, in 1995-1996.

tables. The increasing availability of input-output tables (even at an increasing level of industry detail) evoked proposals for a number of linkage measures, especially between the mid-1950s and the mid-1970s. In particular after the emergence of the endogenous growth theory (with its emphasis on technological spillovers from R&D activities) in the mid-1980s, the analysis of technological linkages between industries has got quite a lot of attention. In this section, both types of linkage analysis will shortly be discussed. For much more comprehensive surveys of the two strands of literature, the interested reader is referred to e.g. Miller & Lahr (2001) and Los (1999, Ch.3), respectively.

2.a Trade linkages

The analysis of trade linkages between industries got an impetus after Hirschman's (1958) statement that developing countries should aim at promoting industries with strong linkages. Growth of these industries would cause growth of other industries as well, and would thereby stimulate the entire economy. At first instance, linkage measures focused on so-called 'backward linkages'. Backward linkages are due to the fact that industries need more inputs grow. Consequently supplier industries cannot but raise their output, which causes more demand for its inputs, and so on. Most well-known are the early contributions by Chenery & Watanabe (1958), who proposed the use the column sums of the matrix **A** (which indicates the requirements per unit of output), and Rasmussen (1956), who advocated the use of the Leontief inverse $(\mathbf{I}-\mathbf{A})^{-1}$ to take indirect effects in more upstream industries into account. In a much more recent article, Dietzenbacher (1992) introduced a refinement on the basis of Perron-Frobenius vectors of both matrices.

Rasmussen (1956) also proposed a measure of 'forward linkages', that is, the extent to which other industries are able to increase their production due to the fact that the additional outputs of the industry considered can be used as additional intermediate inputs. This approach does not fit into the demand-driven nature of the Leontief input-output model, but received support from Ghosh's (1958) introduction of the supply-driven input-output model. After Oosterhaven's (1988) convincing arguments against this model and Dietzenbacher's (1997) equally convincing claim that the Ghosh model should not be viewed as a quantity model but as a price model instead, the analysis of forward linkages lost much of its interest from a development point of view.[2]

The traditional measures of backward linkages answer the question "to what extent does aggregate gross output in the economy decrease due to a reduction of final demand (consumption, investment, exports) for goods produced by industry *i*?" As long as industry *i* delivers some of its output to other industries for intermediate input purposes, this approach cannot answer the question what would happen if the industry would completely cease to exist. This question, which is paramount to this paper, can be addressed by a related type of analysis, called 'hypothetical extraction analysis'. Several approaches have been proposed, not only in country studies, but also in regional applications (see the survey by Miller & Lahr, 2001). The discussion here will be restricted to hypothetical extractions which consider so-called 'total linkages', although some authors argue that an explicit distinction between

[2] The appropriate interpretation of forward linkages is still a point of debate among contributors to the literature. Miller & Lahr (2001, p. p.418-419), for example, argue that specific analyses based on the demand-driven Leontief quantity model could still be seen as a measure of forward linkages.

backward and forward linkages would be preferable (see Dietzenbacher & Van der Linden, 1997). Although similar (interregional) analyses with a different aim were conceived earlier (a.o. Miller, 1966), the following approach is often attributed to Strassert (1968). It was empirically implemented at a much later stage by, among others, Schultz (1977), Meller & Marfán (1981) and Milana (1985). Denote the matrix of input coefficients (inputs required per unit of output) as the partitioned matrix **A**, final demand by industry by the partitioned vector **y** and gross output by industry by the partitioned vector **q**:[3]

$$\mathbf{A} = \left[\begin{array}{c|c} a_{11} & \mathbf{a}_{12} \\ \hline \mathbf{a}_{21} & \mathbf{A}_{22} \end{array}\right], \quad \mathbf{y} = \begin{bmatrix} y_1 \\ \hline \mathbf{y}_2 \end{bmatrix} \quad \text{and} \quad \mathbf{q} = \begin{bmatrix} q_1 \\ \hline \mathbf{q}_2 \end{bmatrix}$$

Now, two situations can be compared. The first starts from the 'real' situation. Using the standard Leontief inverse $(\mathbf{I}-\mathbf{A})^{-1}$, gross output levels are found as $\mathbf{q} = (\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}$. In the second situation, it is assumed that industry 1 does not exist in the economy under consideration.[4] This means that industry 1 does not deliver any inputs to itself ($a_{11} = 0$), that the other industries rely on imports for their intermediate use of the commodity produced by 1 ($\mathbf{a}_{12} = \mathbf{0}$), that industry 1 does not use any of the other industries' inputs ($\mathbf{a}_{21} = \mathbf{0}$) and that final demand for commodity 1 is satisfied by imports ($y_1 = \mathbf{0}$). Applying the demand-driven Leontief model to the adapted final demand vector $\mathbf{y}^*$ and the adapted input coefficients matrix $\mathbf{A}^*$, yields a new output vector $\mathbf{q}^*$, with elements equal or smaller than in **q**. Then, the 'importance' of industry 1 can be measured by the absolute or relative difference between the summed gross output levels $\mathbf{e}'\mathbf{q}^*$ and $\mathbf{e}'\mathbf{q}$.

In a study for Asian developing countries, Schultz (1977) found that the most important industries as detected by the above-described hypothetical extraction methodology were the manufacturing industries. In particular the food processing industry and the leather products industry stand out. The finding that the food industry is important (in particular in the backward sense) was confirmed by Dietzenbacher & Van der Linden (1997) for developed European countries. Other strategic industries found in their analysis are the transport equipment industry, the metal products industry and the mineral products industry.

2.b Technology linkages

After the upsurge of the endogenous growth literature, many contributions appeared that tried to capture the technology spillovers which had been stressed earlier by scholars in the field of evolutionary economics. As has been stressed by many scholars (see Griliches, 1992), two broad categories of spillovers can be distinguished. The choice for a focus on either of the two implies a choice for one of many different empirical approximations for interindustry spillovers. Such approximations are needed because technology flows are much less tangible than commodity flows.

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[3] Note that the input coefficients, final demand levels and output levels pertain to domestic production. Imported commodities are not explicitly considered.

[4] By appropriate permutation of rows and columns, any of the *n* specified industries can be hypothetically extracted. Further, the analysis can easily be adapted to study the effects of simultaneous extraction of two or more industries.

First, one can stress the productivity effects of so-called 'rent spillovers'. In fact, these do not really belong to the technological externalities as emphasized by the technology-driven growth theories. They relate to the fact that product innovators are generally unable to ask prices for their innovations which fully account for the quality gain over existing products with which they often have to compete. In such a situation, the most widely used price deflators are not able to correct for this. As a consequence, productivity gains are partly ascribed to downstream industries, whereas they do not innovate themselves. From an economy-wide growth perspective, however, such issues of distribution are not too interesting.

Second, the aim of empirical studies can be to estimate the impact of 'pure knowledge spillovers'. This concept starts from the notion that knowledge generated in one industry (for instance, due to its R&D efforts) has some public good features. Hence, other industries can in principle use this knowledge to increase the effectiveness of their own innovative activities, without having to pay the full price for it. Such mechanisms can lead to additional growth through increasing returns to scale effects. It should be borne in mind, however, that the relevance of a given 'unit' of knowledge can vary across industries. For instance, knowledge generated in the electronics industry is likely to be more relevant to the communication equipment industry than to the wooden furniture manufacturing industry. Further, some industries generate much more potentially useful knowledge than others do. Consequently, some industries are relatively important from a technological point of view, in the sense that they produce a lot of knowledge with a high degree of relevance.

In their empirical study of productivity effects of R&D spillovers in U.S. manufacturing, Los & Verspagen (2000) found that high-tech industries are the main generators of spillovers. Next to this unsurprising result, they found that medium-tech industries are the main beneficiaries of spilled technology, in particular when pure knowledge spillover measures were used. Ten Raa & Wolff (2000) used a different setup, in which it is hard to distinguish between rent spillovers and pure knowledge spillovers. Nevertheless, they came up with the intuitively strong conclusion that the main 'engine of productivity growth' is the computer equipment manufacturing industry. In principle, it should be possible to append a kind of hypothetical extraction technique to their analysis, in order to identify the role of specific industries in the economy-wide productivity growth process.

Technology spillovers are not necessarily bounded by national or regional borders. Nevertheless, empirical evidence tells that the impact of spillovers decreases with distance, and also that international spillovers are generally less important than domestic spillovers (see e.g. Jaffe *et al*., 1993, Maurseth & Verspagen, 1999, and Laursen & Meliciani, 2001). Hence, the shutdown of an industry may well lead to a loss of an important source of technological progress, which may not be entirely compensated for by reliance on technology from abroad.

2.c Short evaluation of 'the state of the art'

The main conclusion of this brief overview should be that interindustry analysis has important things to say about the 'keyness' of an industry being part of economic and technological networks consisting of multiple economies. On the other hand is it clear that an

integrated growth framework is still lacking. The hypothetical extraction method is purely static, and does not allow for well-known phenomena like commodity-specific Engel curves, which might well affect the composition of the final demand curve. Putting it somewhat differently, reliance on this technique assumes that both production structures and final demand levels (with and without the extracted industry) will remain unchanged forever, whereas especially fast-growing countries have witnessed quite some structural change. Another important drawback is that it is implicitly assumed that the supposed replacement of domestically produced inputs by imported inputs does not induce further negative effects caused by the worsened current account position. Feedback effects of higher unemployment (for example, though lower wage rates) are considered neither. A clear advantage is that the analysis can be carried out using widely available data only, i.e. input-output tables. Interrelations among industries based on capital good deliveries, however, are not considered at all. Clearly, this may well bias the results against heavy capital users and capital goods producing industries. Finally, and maybe most importantly, opportunities to combine the advantages of input-output tables and knowledge spillover matrices in a growth framework should be explored as soon as possible. Especially the way in which productivity growth translates into output or consumption growth should be a focus. Such an integration will be attempted in the rest of this paper.

3. The Model

The previous section showed that input-output tables and related technological spillover matrices could well be useful empirical tools for the identification of strategic industries, but that existing methodologies that exploit this data suffer from multiple drawbacks. They lack a dynamic perspective, are unable to combine economic and technological linkages into an all-encompassing indicator, they do not take interindustry differences in export performance into account, do not consider the interplay between demand and supply factors and, finally, remain silent with respect to the effects of interindustry flows of capital goods. In this section, a dynamic interindustry model will be developed. It is similar to the R&D-driven growth model proposed by Los (2001). Application of hypothetical extraction methods as described in the previous section would yield indicators of importance that meet most of the above-mentioned disadvantages. In the present version of the model only the drawback with regard to the exclusion of capital good flows cannot be addressed. Preliminary modeling work not presented here, however, indicates that relatively modest changes should suffice to solve this problem.

Recently, the input-output literature has seen a number of contributions in which technology, competitiveness and/or balance of payments issues are integrated in a dynamic framework. Los (1999, Chs. 6 and 7) presented a prototype model, in which elements of a Kaldorian demand-driven economy were combined with elements of R&D-driven, endogenous growth models. This model considers a closed economy, as did Los (2001). This second model, however, followed the endogenous growth literature in assuming supply-driven growth without unemployment. Demand played only a role in determining the

allocation of labor to industries, through endogenously evolving industrial compositions of consumption. Verspagen (1999) included technology-driven competitiveness variables in a macro-economic evolutionary model with a strong emphasis on demand-constrained growth. More specifically, current account equilibrium was modeled as a limiting factor to growth. In Los & Verspagen (2001), substantial parts of Los (2001) and Verspagen (1999) were merged. In their two-country model, the size of the world market is mainly determined by (exogenous) rates of innovation, catching-up and learning-by-doing, but country-specific growth rates are generally different due to specialization patterns, which are endogenously determined by competitiveness levels and current account equilibrium. Finally, Stehrer (2001) offered an interindustry model of international productivity growth were the impact of transitory rents in innovating industries drives investment and growth. Competitiveness is mainly driven by relative costs of heterogeneous labor.

The model proposed in this paper can be seen as a compromise between the above-mentioned supply-driven and demand-driven models.[5] Technological progress does not only yield labor-saving innovations, but also increases competitiveness. This leads to additional export demand. In comparison to Los & Verspagen (2001), the model is simpler with regard to the modeling of international linkages. It is assumed that the country which is studied is neither large enough to affect the sizes of the world markets, nor advanced enough to change the industry-specific rates of worldwide technological progress. The equations that together constitute the model will be introduced in two steps. These correspond to the way in which the model is solved. For each period, an extended static input-output model is solved, given a number of parameters and values which are assumed to be exogenous at the beginning of the period considered. The dynamic nature of the model stems from the second set of equations, which describe how these 'short run-exogenous' variables evolve over time. When a set of initial values is 'fed' to the model, its behavior can be studied by means of simulation analysis.

3.a Short-run solution

As mentioned, capital goods flows (and hence, investment) are excluded from the model. Hence, produced commodities can be used for three purposes. They can be consumed by households, be exported to the rest of the world or be used as intermediate inputs in domestic production processes. In the short-run, it is assumed that the supply of commodities immediately adapts to demand which implies that the *n* (domestic) output levels $\mathbf{q}^{\mathrm{d}}$ (*n*x1 vector) can be expressed as the solution of the standard open Leontief model:[6]

$$\mathbf{q}^{\mathrm{d}} = \left(\mathbf{I} - \mathbf{A}^{\mathrm{d}}\right)^{-1}(\mathbf{c}^{\mathrm{d}} + \mathbf{x}) \qquad (1)$$

in which $\mathbf{I}$ indicates the *n*x*n* identity matrix, $\mathbf{A}^{\mathrm{d}}$ stands for the *n*x*n* matrix of domestically produced intermediate input coefficients, $\mathbf{c}^{\mathrm{d}}$ represents the *n*x1 vector of domestic

[5] In a sense, it has many properties in common with the predator-prey type growth cycle models advocated by Goodwin (1967).

[6] Throughout the paper, matrices will be denoted by bold capitals, vectors will be represented by bold lowercase symbols and scalars (including specific elements of matrices or vectors) by italic lowercase symbols. Hats denote diagonalized vectors and primes indicate transposed matrices or vectors.

consumption demand by industry and $\mathbf{x}$ denotes the nx1 vector of export demand by industry. It should be noted that all matrices and vectors in Equation (1) are expressed in quantities. Price formation will be dealt with below, since prices are assumed to depend on past experience.

The value of each of the domestic input coefficients in $\mathbf{A}^{d}$ is determined by two states of affairs. First, technological conditions determine the total physical amounts of inputs per unit of output, $\mathbf{A}$. In general, parts of the input requirements will be imported, instead of being produced within the region or country considered. It is assumed that domestic inputs and inputs imported from abroad do not differ in a qualitative sense, but are perfectly competitive. If the trade shares (by commodity) at the beginning of the period are denoted by the nx1 vector $\mathbf{t}$, the matrix $\mathbf{A}^{d}$ in Equation (1) can be written as[7]

$$\mathbf{A}^{d} = \hat{\mathbf{t}}\mathbf{A} \tag{2}$$

The vector of consumption demand for domestically produced inputs $\mathbf{c}^{d}$ results from the interplay of four factors. First, it is assumed that the total amount of money to be consumed is given at the beginning of the period. Second, a determinant of consumption demand by industry is the structure of consumption. Although several specifications may be defendable, the households are supposed to spend fixed fractions of their consumption outlays on each of the n goods. As will be clarified below, these shares can change over time. For some goods, part of the consumption demand will be imported. These shares are given by the vector $\mathbf{t}$, which was introduced in the discussion of imported intermediate inputs. Finally, of course prices play an important role in the determination of consumed quantities. Both the prices of domestically produced and imported consumption goods are important in this respect. Denoting these price vectors by $\mathbf{p}^{d}$ and $\mathbf{p}^{row}$ (in a common currency), respectively, and taking them for granted at the beginning of each period, the elements of the consumption vector of domestically produced goods $\mathbf{c}^{d}$, and the consumption vector of imported goods $\mathbf{c}^{row}$ can be expressed as

$$c_i^{d} = \frac{s_i t_i}{p_i^{d} t_i + p_i^{row}(1-t_i)}\tilde{c} \qquad \text{and} \qquad c_i^{row} = \frac{s_i (1-t_i)}{p_i^{d} t_i + p_i^{row}(1-t_i)}\tilde{c} \tag{3}$$

with s_i indicating the share of good i in total nominal consumption, and $\tilde{c}$ denoting this consumption level in nominal terms.[8]

Given the form of Equation (1), the export vector should also be specified. The elements of this vector are assumed to be determined by two factors. First, it is assumed that the sizes of each of the n world markets are given at the beginning of each period. These sizes are represented by the nx1 vector $\mathbf{z}^{row}$. The 'small country' assumption adopted here ensures

[7] This specification assumes that the fraction of inputs accounted for by domestic producers can well vary from commodity to commodity, but is identical for all industries that use a specific commodity. Actually, it will be assumed below that these do not differ between intermediate inputs and consumption goods. In empirical applications, this assumption appears to be invalid. In their labor productivity growth decomposition, Dietzenbacher *et al.* (2000) therefore use a more general formula.

[8] Throughout the paper, variables in real terms will never be explicitly labeled as such. Nominal variables will always be indicated by a tilde.

that developments in the country considered do not change the world markets. Second, the commodity-specific shares of the country in world trade (related to competitiveness) $\mathbf{t}^z$ will be assumed as given at the beginning of the period:

$$\mathbf{x} = \hat{\mathbf{t}}^z \mathbf{z}^{row} \tag{4}$$

Simultaneously with the output levels $\mathbf{q}$, the inputs of labor (assumed to be homogeneous) and imports by industry are determined. The *n*x1 labor inputs vector is given by

$$\mathbf{l} = \hat{\mathbf{l}}^c \mathbf{q}^d \tag{5}$$

where the coefficients in the *n*x1 vector $\mathbf{l}^c$ represent the labor requirements (in quantity terms, say man years) per unit of output, which are assumed to be given at the beginning of the period. The *nxn* matrix of imports by industry and commodity can be expressed as

$$\mathbf{M} = (\mathbf{I} - \hat{\mathbf{t}})\mathbf{A}\hat{\mathbf{q}}^d \tag{6}$$

The solution of the short-run part of the model as given by Equations (1-6) is important in shaping the long-run behavior of the model as will become evident from the discussion below.

3.b Intertemporal relations

In this part of the model, the development over time of variables that were assumed to be exogenous in the determination of the short-run solution will be discussed.

Requirements per unit of output

Like in Los (1999, 2001) and Los & Verspagen (2001), technological progress is assumed to leave the matrix of physical input-output coefficients of $\mathbf{A}$ unaltered. Instead, the labor coefficients per unit of output contained in $\mathbf{l}$ decrease over time. As opposed to the studies mentioned, rates of technological progress are supposed to be exogenous. That is, for reasons of simplicity, well-known sources of technological progress like R&D activities, catching-up through imitation and learning-by-doing (Kaldor-Verdoorn mechanisms) will not be made explicit here. However, the rate attained in any single industry is assumed to be dependent on the rates attained in other industries. This reflects the positive interindustry spillovers associated with knowledge generation as surveyed in the previous section. In many senses, the proposed specification is in line with the empirical approach of Ten Raa & Wolff (2000). It will be assumed, however, that industries benefit not only benefit from domestic technological developments, but also from new technology generated abroad. These assumptions boil down to

$$\mathbf{l}^c[t+1] = \left(\mathbf{I} + \hat{\underline{\rho}}[t]\right)^{-1} \mathbf{l}^c[t] \tag{7a}$$

$$\rho_i[t+1] = \rho_i^* + \sum_{j \neq i} \eta_{ij}^d t_j[t] \rho_j[t] + \sum_{j=1}^{n} \eta_{ij}^{row} (1 - t_j[t]) \rho_j^{row} \quad (8)$$

The elements of the *n*x1 vector $\boldsymbol{\rho}$ represent the rates of technological progress by industry. They vary from period to period, due to the fact that trade shares fluctuate, and the spillovers from domestic industries will generally be different from those obtained from foreign industries. The first term of the right-hand side of Equation (8) indicates the 'autonomous' rate of technological progress (which will, for instance, be affected by the industry's R&D intensity). The second term denotes the effects of domestic spillovers from other industries. The symbol η_{ij}^a ($0 \leq \eta_{ij}^a \leq 1$) indicates to what extent technological progress in industry *j* affects progress in *i*. The relative importance of this effect is assumed to be proportional to the share of inputs bought in the own economy. The third term indicates a similar effect from international (or interregional) spillovers. It should be noted that this term includes an effect from industry *i* itself, contrary to the domestic term. This reflects the possibility that technology from foreign competitors yields progress, either through outright imitation of production processes, or as a consequence of the emergence of new ideas in the own research activities after assimilation of the foreign knowledge.

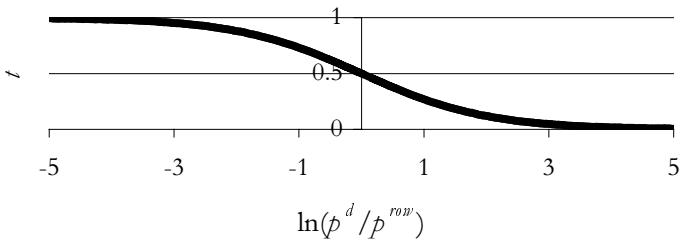
Technological progress in the rest of the world is also supposed to be reflected in changes in the (foreign) labor coefficients, at the constant exogenous industry-specific rates $\boldsymbol{\varrho}^{row}$:

$$\mathbf{l}^{c,row}[t+1] = \left(\mathbf{I} + \hat{\boldsymbol{\varrho}}[t]\right)^{-1} \mathbf{l}^{c,row}[t] \quad (7b)$$

International competitiveness

The trade shares evolve over time as a consequence of changes in relative prices. The approach adopted by Los & Verspagen (2001) will be followed here. They used the concept

Figure 1: Trade Shares



of an (inverted) logistic curve, as illustrated in Figure 1, to determine the trade shares for each of the commodities in each of the industries.

In mathematical terms, these relations between the ratios of domestic prices to foreign prices and the 'equilibrium' trade shares on domestic and world markets, respectively, can be expressed as follows :

$$\bar{t}_i[t+1] = 1 - \frac{1}{1 + e^{-\left(\ln \frac{p_i^d[t]}{p_i^{row}[t]} - \varepsilon_i^d\right)/\varphi_i^d}} \qquad \text{and} \qquad \bar{t}_i^x[t+1] = 1 - \frac{1}{1 + e^{-\left(\ln \frac{p_i^d[t]}{p_i^{row}[t]} - \varepsilon_i^x\right)/\varphi_i^x}} \tag{9}$$

The parameter ε can be interpreted as the value of the logarithm of the price ratio for which the trade shares are 0.5. For perfectly tradable goods this parameter will equal zero, but for most goods the price ratio corresponding to equal market shares will have a positive value. In this case, the market shares of domestically produced inputs will be larger than fifty percent when prices are equal. The extent to which the market share at the unit price ratio differs from fifty percent is also dependent on the parameter φ(>0), which represents the commodity-specific sensitivity of trade shares to changes in the price ratio. The lower φ, the more sensitive the trade shares are. The parameters φ may be affected by a number of things, such as costs of transportation and trade barriers.[9]

An adjustment process, in which the gaps between the actual trade shares **t** and the 'equilibrium' trade shares $\bar{\mathbf{t}}$ vanish gradually in the absence of shocks:

$$\mathbf{t}[t+1] = (1 - \delta^t)\mathbf{t}[t] + \delta^t\left(\bar{\mathbf{t}}[t+1]\right) \tag{10}$$

with δ^t $(0 \le \delta^t \le 1)$ denoting the speed of adjustment parameter.

Prices, wage rates and the exchange rate

The specification of trade share dynamics naturally leads to the question what factors drive prices. The Leontief price model (a well-known tool in input-output analysis) yields an expression for 'equilibrium prices', which are defined as the unique set of prices for which revenues and costs equal each other for all industries, given prices of primary inputs like labor and imports. It will be assumed that prices gradually adjust to these equilibrium prices:[10]

$$\mathbf{p}^{\mathbf{d}}[t+1] = (1 - \delta^p)\mathbf{p}^{\mathbf{d}}[t] + \delta^p \bar{\mathbf{p}}^{\mathbf{d}}[t+1] \tag{11}$$

in which δ^p $(0 \le \delta^p \le 1)$ is the price adjustment parameter. The equilibrium price vector is given by

$$\bar{\mathbf{p}}^{\mathbf{d}\prime}[t+1] = \left(w[t]\mathbf{l}'^{\mathbf{c}}[t] + \mathbf{p}'^{\mathbf{row}}[t](\mathbf{I} - \hat{\mathbf{t}}[t])\mathbf{A}\right)\left(\mathbf{I} - \hat{\mathbf{t}}[t]\mathbf{A}\right)^{-1} \tag{12}$$

Equation (12) includes two variables that deserve more discussion. First, the *nominal* wage rate *w*. This rate will be assumed to fluctuate around 1. In many input-output models the

[9] Note that the parameters ε and φ are allowed to differ between trade shares on domestic markets and world markets.

[10] Note that there are two kinds of lags in the adjustment towards equilibrium prices as specified in Equations (11-12). First, prices are assumed to be based on wages, import prices and required quantities of the previous period. Consequently, it will always take one period to adapt to equilibrium, even if the speed of adjustment parameter would be set equal to 1.

wage rate is set exactly equal to this value, so that it can serve as a 'numéraire'. Because decreasing labor requirements per unit of output lead to lower prices in specifications like Equation (12), the *real* wage rate will rise due to technological progress. To introduce supply-side elements in the model (which is mainly driven by demand, see Equation (1)), the nominal wage rate is allowed to rise in times of low unemployment. The wage rate dynamics is specified as a type of Phillips curve:

$$w[t+1] = \left(\frac{1}{\bar{l}} \frac{\mathbf{e}'\mathbf{l}[t]}{l^{\sup}[t]} \right)^{\delta^w} \tag{13}$$

In this equation, $\bar{l}$ indicates a 'natural' rate of employment, **e** is the *n*x1 summation vector (which consists of ones) and $l^{\sup}$ denotes labor supply.[11] The sensitivity of the nominal wage rate is given by the wage rate adjustment parameter δ^w (>0).

Second, the import prices $\mathbf{p}^{\mathbf{row}}$ should be elaborated upon, in order to give a sensible interpretation to Equation (12). The dynamics with respect to these prices result from two factors, price developments measured in foreign prices and changes in the exchange rate. With regard to the first factor, it will be assumed that a specification similar to Equations (11-12) applies. The only difference lies in the small country assumption, which implies that foreign prices are not influenced by (export) prices of the country considered and that trade shares with respect to inputs remain constant over time. Further, the foreign nominal wage rate is assumed to remain equal to 1. Finally, the input-output coefficients in **A** are assumed to hold for foreign economies as well. These assumptions lead to

$$\mathbf{p}^{\mathbf{row,f}}[t+1] = (1-\delta^p)\mathbf{p}^{\mathbf{row,f}}[t] + \delta^p \bar{\mathbf{p}}^{\mathbf{row,f}}[t+1] \tag{14}$$

in which the superindex **f** indicates that these variables are expressed in a foreign currency. The equilibrium price vector is given by

$$\bar{\mathbf{p}}^{\mathbf{row,f}\prime}[t+1] = \mathbf{l}^{\mathbf{c,row}\prime}[t]\left(\mathbf{I} + \hat{\boldsymbol{\varrho}}^{\mathbf{row}}\right)^{-1}\left(\mathbf{I} - \mathbf{A}\right)^{-1} \tag{15}$$

The dynamics of the exchange rate χ (the price of the national currency expressed in the international currency, $\mathbf{p}^{\mathbf{row}} = \chi \mathbf{p}^{\mathbf{row,f}}$) is specified such that it gradually adjusts towards an equilibrium value that would imply current account equilibrium. Thus, if the economy exports less than that it imports, the national currency will devaluate, which improves the competitiveness of the economy and hence (under the assumption that the Marshall-Lerner condition is fulfilled) its current account position:

$$\chi[t+1] = (1-\delta^\chi)\chi[t] + \delta^\chi \bar{\chi}[t+1] \tag{16}$$

δ^χ ($0 \leq \delta^\chi \leq 1$) indicates the speed of adjustment. The equilibrium exchange rate is given by

[11] For reasons of simplicity, the model assumes that labor supply is fixed over time, which more or less implies that the size of the population is held constant.

$$\overline{\chi}[t+1] = \frac{\mathbf{p}'^{\text{row,f}}[t]\left(\mathbf{M}[t]\mathbf{e} + \mathbf{c}^{\text{row}}[t]\right)}{\mathbf{p}'^{\text{d}}[t]\mathbf{x}[t]} \tag{17}$$

The level and composition of consumption

In most Keynesian and neoclassical models, households allocate part of their earnings to current consumption and the rest to savings. Savings are used for investments in physical or knowledge capital by firms, and earn the savers additional future income through dividends and / or interest payments. In this simplified model without any kind of investment, it would seem strange to assume any savings. Instead, it will be assumed that all income (stemming from wage payments) is consumed in the next period. This implies that the consumption level in nominal terms can be written as

$$\tilde{c}[t+1] = w[t]l[t] \tag{18}$$

The consumption shares by commodity **s** evolve according to a process that involves the possibility that demand elasticities with respect to income are commodity-specific. To this end, a discrete-time variant of a specification originally proposed in Verspagen (1993) and applied in Verspagen (1999) and Los (2001) is adopted. This specification ensures that the consumption shares add up to one for each period, if this condition is met in the initial period:

$$\mathbf{s}[t+1] = \mathbf{s}[t] + \left[\hat{\mathbf{s}}[t]\mathbf{T}\left(\mathbf{s}[t] - \mathbf{s}^*\right) - \left(\hat{\mathbf{s}}[t] - \hat{\mathbf{s}}^*\right)\mathbf{T}'\hat{\mathbf{s}}[t]\right] \cdot \left(c[t] - c[t-1]\right) \tag{19}$$

with the real consumption level defined as $c^d = \mathbf{e}'\mathbf{c}^{\text{d}}$. In this specification, $\mathbf{s}^*$ represents the consumption shares that would prevail at an infinitely high real consumption (per capita) level. The elements τ of matrix **T** indicate how quickly actual consumption shares adapt to $\mathbf{s}^*$. If **T** is chosen to have zeroes on the main diagonal and sufficiently small nonnegative values elsewhere, negative shares will not occur and actual shares will converge monotonically to their asymptotic values if real consumption grows.

The sizes of world markets

As mentioned in the previous subsection, export levels are partly determined by the sizes of the world markets. One could opt for a full two-country model in which foreign consumption and input requirements are endogenously determined (see, e.g., the model presented by Los & Verspagen, 2001). Empirical implementations of such models would put an even higher strain on the availability of data than a single country model as the one proposed here. Hence, a very simple specification is chosen, in which each of the *n* world markets grow at exogenous, constant, commodity-specific growth rates:

$$\mathbf{z}^{\text{row}}[t+1] = \left(\mathbf{I} + \hat{\mathbf{g}}^{\text{z}}\right)\mathbf{z}^{\text{row}}[t] \tag{20}$$

Together, Equations (1-20) constitute the dynamic model that is proposed to analyze the importance of specific industries for the economy as a whole.[12] Shutdown of an industry has several implications, ranging from less exports (and hence, devaluation) to higher unemployment (and hence, wage reductions) and less beneficial interindustry technology spillovers (and hence, less technological progress). However, counterbalancing effects are present, such as a lower wage rate and a tendency towards devaluation, which both increase the competitiveness of the remaining industries. Before the strategic importance of industries will be analyzed in more detail, the dynamic behavior of the model as it emerges from the interplay of the equations should be studied.

4. Simulations: Behavior of Key Variables

As may have become clear from the specifications of the short-run and intertemporal equations in the previous section, the model is too complicated to be solved by analytical means, especially as a consequence of its industry detail. Hence, its plausibility cannot be assessed in any other way than by simulation analysis. In this section, results for key variables like aggregate consumption, unemployment, nominal and real wage rates, trade shares and exports will be studied. To this end, a baseline scenario was set up, consisting of a set of parameter values and initial values for the dynamic variables. These values can be found in the Appendix.

In the hypothetical economy considered, three industries are specified. In the baseline scenario, the industries are very much alike in many respects. Most importantly, both within and outside the economy, the rates of technological progress are identical, at 2% per period. In the baseline scenario, interindustry spillovers are set equal to zero. The world markets grow at the same pace for all three industries, also at 2%. The industries differ to some extent with respect to the tradability of the commodities they produce. Further, the initial shares in consumption and the labor force are different, industry 1 being most labor-intensive (in terms of labor per unit of gross output), and industry 2 enjoying the largest part of the consumption expenditures. The adjustment parameters vary in size: exchange rate movements are assumed to be rather gradual, whereas adjustments in prices and trade shares towards their equilibrium values are treated as rather prompt. Further, it should be noted that the initial rates of technological progress are set equal to their corresponding parameter values. This is done to minimize the shock which is due to the start-up of the simulation. Since it is virtually impossible to specify an initial situation which would imply an 'equilibrium' situation, temporary shocks in the beginning of the simulation interval are almost inevitable, even without extracting an industry.[13] This phenomenon clearly emerges from the simulation results depicted in Figures 2a-2.

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[12] Note that the input-output tables that could be constructed for each period are not completely balanced when expressed in current prices, due to the fact that Equations (11-17) do not yield equilibrium prices for the period itself (even if the adjustment process in Equation (11) would be instantaneous). The relatively small disturbances are of an ambiguous sign.

[13] Two comments should be made in this respect. First, a not too unstable adjustment process after a shock should be seen as a virtue of a model. Many dynamic input-output models suffer from severe instabilities as soon as the initial situation cannot be characterized as 'on the balanced growth path'. Second, the initial values

Figure 2a

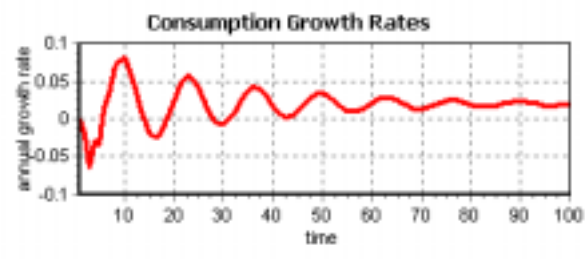

Figure 2b

Figure 2c

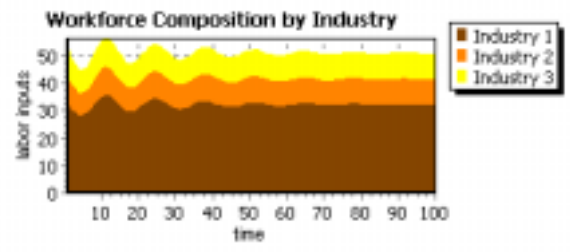

Figure 2d

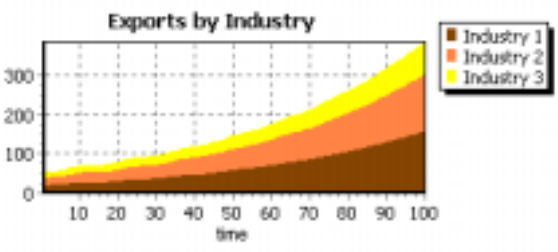

Figure 2e

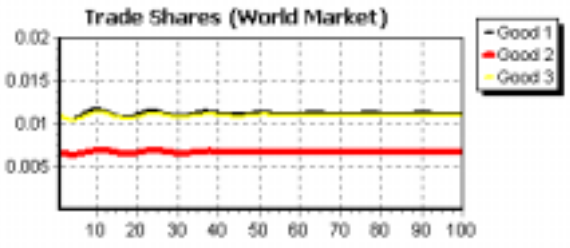

Figure 2f

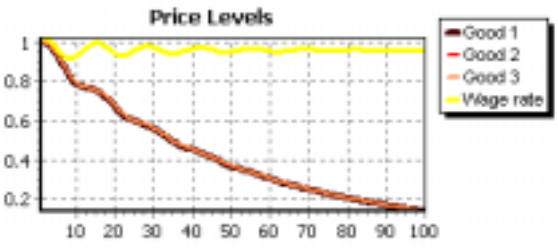

Figure 2a shows that the annual consumption growth rate fluctuates around the positive rate implied by the technological growth rates (=0.02). The amplitude of the growth rate decreases over time. Additional simulations (not documented here) learn that the dampening of the cycles is stronger for faster price adjustment processes, but that the initial amplitude is larger for fast adjustment. The cyclical behavior is also reflected in the evolution of the employment rate (Figure 2b), which slowly settles down at the specified natural rate of employment (=0.85).[14] As Figure 2c and 2d indicate, the compositions of the work force and export demand remain stable over time, which is due to the choice of parameters. In case of different rates of technological progress (between economies or between industries) and/or substantial differences in the sensitivity of trade shares (see Figure 2e) to prices, the pattern would be less symmetric. Finally, the nominal wage rate settles at a value just below 1, after cycles with downturns nearly corresponding to upturns in the employment rate, due to the Phillips curve effect. In the baseline scenario, prices decrease steadily. Hence, the real wage rate rises over time.

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of the dynamic variables could be chosen in a better way, for example by specifying values of the initial and pre-initial consumption levels that are in line with positive technological progress. Such improvements will be implemented in a next version of the paper.

[14] Note that a stable long-run employment rate requires that the (aggregate) world market growth rate is identical to the (aggregate) rate of technological progress. Otherwise, the asymmetric competition positions (no Phillips curve in the rest of the world) will yield undesirable model properties, such as employment rates forever exceeding one. The restrictive parameter choice could be relaxed somewhat by including a positive rate of labor supply (i.e. population) growth.

The results for the baseline scenario indicate that the model can generate desirable outcomes. The evidence presented so far, though, is certainly insufficient to assess the quality of the model. Such an assessment would require a great deal of sensitivity analysis, by reports on the behavior of key variables for several parameter configurations. For reasons of space, however, this approach will not be chosen here.[15] Instead, the plausibility of the model will be tested in a more indirect way, by presenting results obtained for simulations in which an industry is hypothetically extracted from the economy.

5. Simulations: Identification of Strategic Industries

This section will show how the model developed in Section 3 and simulated in Section 4 could be used to gain insight into the importance of specific industries for an entire economy, taking economic, technological and current account issues into account. To this end, the hypothetical extraction method described in Section 2 will be used. By choosing strongly negative values for ε_i^d and ε_i^x (which indicate that the price ratio should be extremely favorable to the domestic country to gain a market share of 0.5) and a very small value for φ_i^d and φ_i^x (which mean that trade shares are very sensitive to changes in relative prices), an industry can easily be extracted from the economy. To offer an idea of what happens when industry 3 is extracted from the baseline scenario, Figures 3a-c depict the behavior of three key variables, the consumption growth rate, the price levels and the trade shares, for $\varepsilon_3^d = \varepsilon_3^x = -15.0, \varphi_3^d = \varphi_3^d = 0.0001$.

Figure 3a

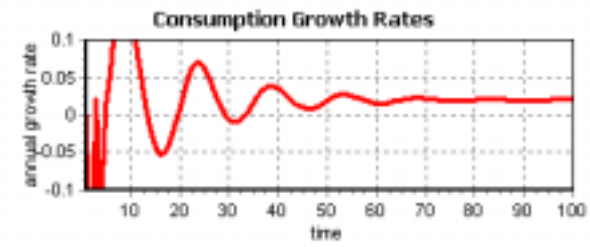


Figure 3b

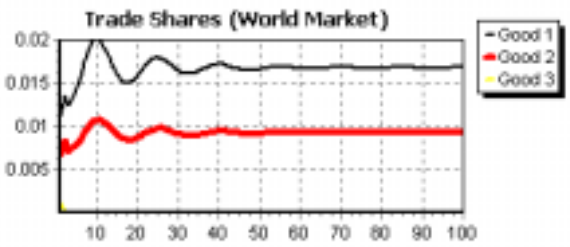


Figure 3c

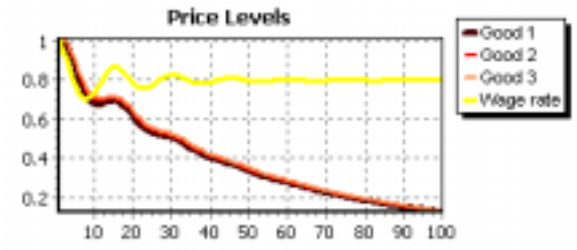


Figure 3a shows that the long run rate of consumption growth does not change. The economy does not produce good 3 any longer, but due to the fact that technological progress is equally fast in the other industries, this has no effects. The negative shocks in the first five periods, however, cause lower real consumption *levels* (compared to the baseline scenario)

[15] Simulation results for specific sets of parameter values can be obtained from the author.

for the entire period. Figure 3b shows that the trade share of the extracted good 3 decreases to zero indeed, after a short adjustment process of about two years. On the other hand are the trade shares of the other two goods significantly higher than in the baseline scenario, at least for this specific parameter configuration. The reason for this emerges clearly from Figure 3c: the (nominal) wage rate remains much lower, due to the high rates of unemployment in the first periods after the shutdown of industry 3. Hence, the price competitiveness of industries 2 and 3 is enhanced.

The results depicted in Figure 3 may well be very specific for the parameter value configuration chosen. In the remainder of this section, more systematic comparisons will be presented, in which the importance of the extracted industry is made to vary with respect to one parameter at a time. Like in the hypothetical extraction analysis applied to static input-output tables, for every parameter setting two situations will be compared. Instead of comparing output levels added over industries as in much of the original extraction literature, the importance of an industry will be measured by the ratio of the net present value of consumption for the economy without and including the industry under consideration. Further, the differences in rates of unemployment (averaged over the simulation period) will be used as an indicator of differences in welfare.

First, variation in the autonomous rate of innovation in industry 3 (both domestic and foreign) will be considered. That is, $\rho_3^* = \rho_3^{row}$ (as are the initial values of $\rho_3[t]$), but at various levels. Consequently, rates of technological change will differ between industries.

Figure 4: Importance as function of worldwide technological progress.

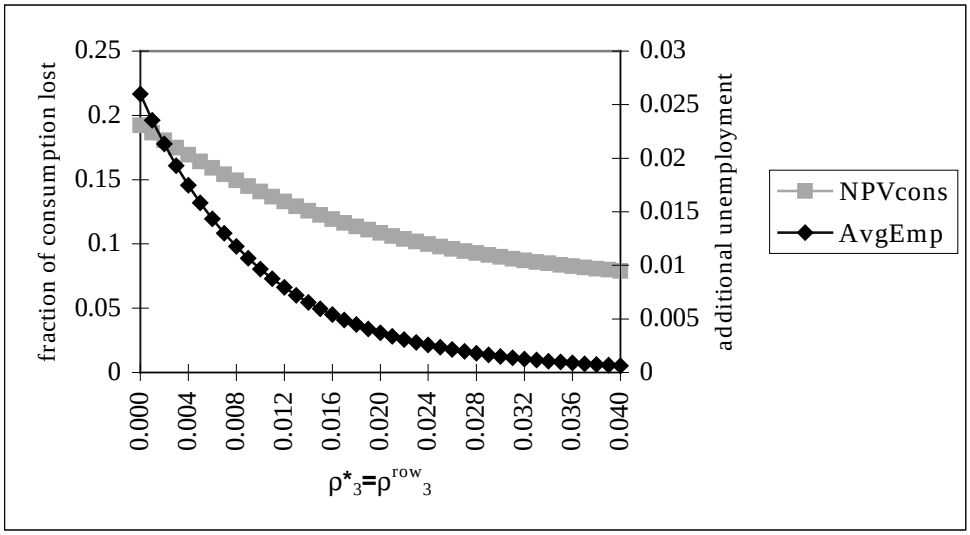
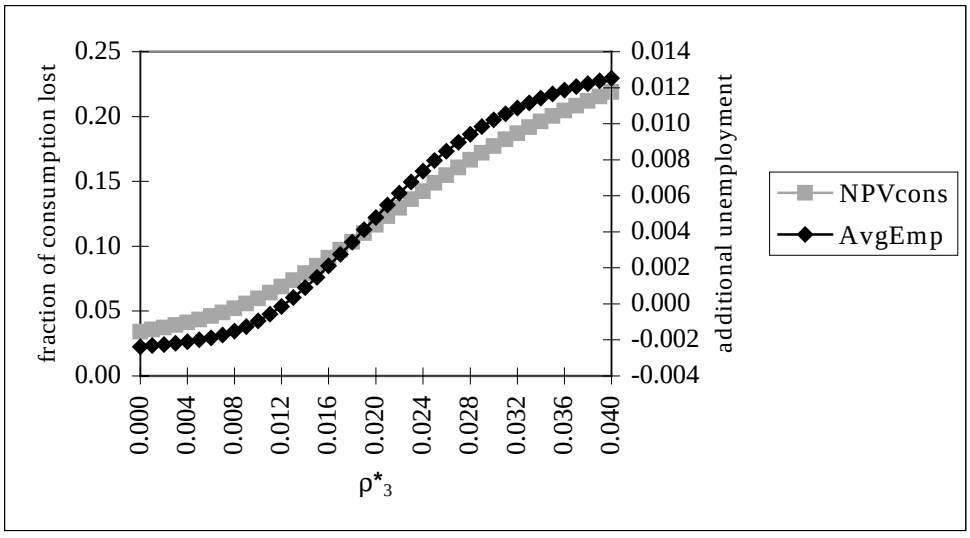


Figure 4 presents a somewhat paradoxical picture. The faster technological progress in the extracted industry, the less is the impact of extraction on the economy. In the absence of technological progress in this industry and in its foreign competitors, shutdown would lead to a loss of about 20% of discounted consumption streams (left hand vertical scale) and an increase of the average unemployment rate by approximately 2.3%. If the same industry had opportunities to attain a 4% annual rate of technological progress, however, the unemployment effects of shutdown would be negligible and the loss of discounted

consumption would amount to just 8%. This is result runs counter to intuition, which says that high-tech industries are essential for economies. In this model, though, high-tech implies that labor is saved at a fast pace. Hence, more and more labor inputs are reallocated to industries with less technological progress. Consequently, the difference between a small number of workers in industry 3 and no workers in industry 3 at all due to shutdown is relatively small. Further, the higher unemployment in the periods following shutdown lead to consistently lower wages and hence a positive effect on the competitiveness of the other two industries. In case of no technological progress in industry 3, more and more people become employed in this industry. Shutdown would thus leave many people unemployed. This time, the other industries do not benefit sufficiently from trade share effects of low wages caused by unemployment in industry 3 to make up for this. Instead, continued wage reductions lead to a lack of effective demand and the effects of shutdown turn out to be substantial.

A different situation emerges from Figure 5, in which the domestic autonomous rate of technological progress in the industry to be extracted is varied, but technological progress in the rest of the world is assumed to be as in the baseline scenario (at 2% per annum). Now, the importance increases with the rate of technological progress. At high rates, shutdown would mean the loss of an industry that is very capable of gaining increasing market shares. The importance of the industry rises most strongly in the region of innovation rates that correspond to the foreign innovation rate. In this region, market shares are also the most sensitive. In fact, Figure 5 reflects the logistic trade share curve sketched in Figure 1.

Figure 5: Importance as function of domestic technological progress.



Note that for low rates of innovation, extraction of the industry would even have beneficial effects on the average rate of unemployment. In this case, shutdown prevents the domestic economy from producing a good in a very inefficient manner. Instead, the good is imported at cheaper rates, through which the other two goods can be sold at lower prices. This has a positive effect on trade shares and leads to more than compensating employment in industries 1 and 2.

Figure 6: Importance as function of consumption dynamics.

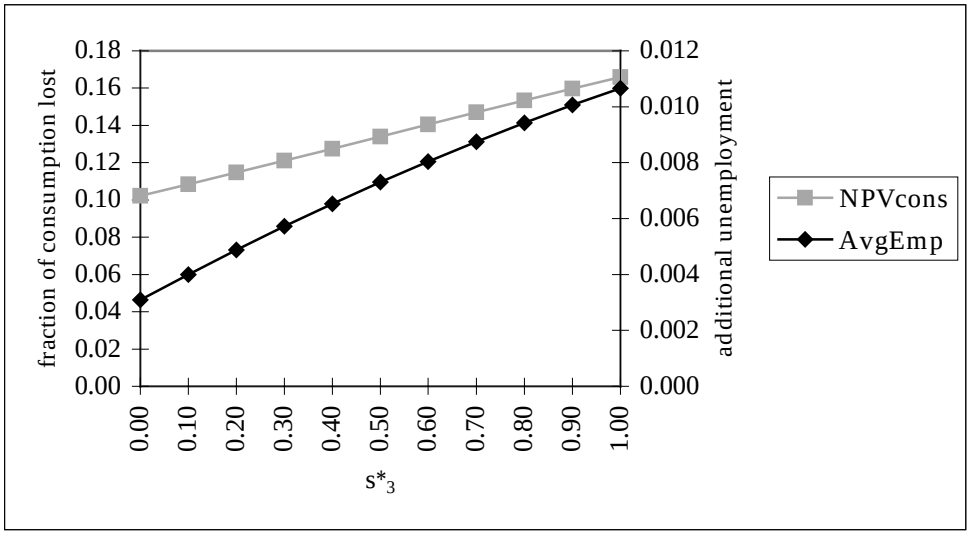
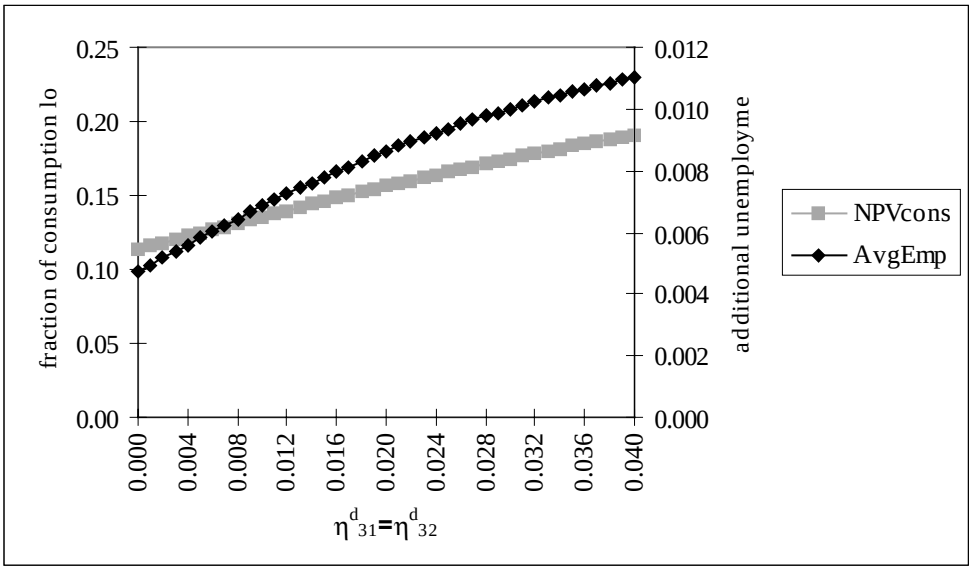


Figure 6 gives an indication of the importance of the dynamics of consumption shares. The numbers on the horizontal axis denote the asymptotic consumption share (in the domestic economy) of good 3 at infinitely high real consumption levels. It is assumed that the other two asymptotic consumption shares change in proportion to their baseline scenario values. The tendency is clear: the more favorable consumption share dynamics are to the extracted industry, the more important it is in terms of consumption levels and unemployment rates. It should be noted, though, that the slope of both curves in Figure 6 depend heavily on the relative size of the domestic economy and the world economy: the values for the growth rates of the world markets for the three goods are maintained as in the baseline.

Figure 7: Importance as function of spillover-generating ability.



Finally, Figure 7 shows how variations in the ability to generate spillovers to other domestic industries affect the importance of an industry. Both the net present value of real consumption and the average unemployment rate are most negatively affected by a

closedown if the industry provides other industries with relatively much knowledge. These spillovers enhance the rate of technological progress in the entire economy, and thus do the other industries also benefit in terms of international competitiveness.

The analysis presented in this section aimed at offering a flavor of the type of results the dynamic extraction method proposed in this paper can produce. Of course, the analysis has been very partial. In particular, the interaction between variations in two or more parameters may yield results which have not been revealed here. As such, the two-dimensional analysis of parameter value variations in Los (2001) might constitute an insightful extension to the concise analysis presented here.

6. Conclusions

This paper started off by arguing that existing measures of the importance of industries to national or regional economies do not offer a coherent indication. On the one hand, input-output methodologies are used to take trade linkages into account. On the other hand, a relatively new literature on technological influences between industries has emerged. So far, however, an integrative framework that also considers potentially important current account developments has not been proposed. The aim of this paper has been to present such a framework based on a technology-driven dynamic input-output model with supply-side and demand-side elements. Simulation analysis on a simplified, hypothetical economy was carried out to assess the main properties of the model and the consequent indicators of importance of industries.

The model can probably be improved with regard to at least two aspects. First, capital goods should be included. In the present version of the model, trade linkages between industries are solely due to intermediate inputs. In reality, though, many industries deliver large parts of their output as capital goods. Inclusion of capital goods would not only capture important empirical linkages, it would also enable analysis of the effects of product innovation. Until now, technological change enters the system through labor-saving process innovations only. Secondly, it should be expected that a model specification in continuous time would further enhance the stability of the model behavior in the short run. The fact that the model in discrete time can ‘handle’ shocks in which an industry that employs 15 to 20 percent of the labor force is suddenly eliminated seems a good sign in this respect.

The most important thing, however, is to calibrate the model as well as possible to one or more real world economies. It will certainly prove to be a huge job to gather all the data and estimates of parameters that are required for such an exercise, but it would probably yield important insights into the societal value of particular endangered industries. Further, it would perhaps be possible to give indications of the value of starting-up a new industry in developing countries. In this way, the model could contribute to the interindustry approach advocated by Hirschman (1958) in his attempts to identify strategic industries.

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Appendix

Parameter values for baseline scenario

```
0.2         deltachi
0.85        deltap
0.9         deltat
0.2         deltaw
0.03        disc
0.85        lbar
60.0        lsup

0.140       epsilond(i)
0.140
0.075

-1.125      epsilonx(i)
-1.25
-1.125

0.10        phid(i)
0.10
0.10

0.25        phix(i)
0.25
0.25

0.02        gz(i)
0.02
0.02

0.02        rhorow(i)
0.02
0.02

0.02        rhostar(i)
0.02
0.02

0.36363     sstar(i)
0.45455
0.18182

0.00 0.00 0.00          etad(i,j)
0.00 0.00 0.00
0.00 0.00 0.00

0.00 0.00 0.00          etarow(i,j)
0.00 0.00 0.00
0.00 0.00 0.00

0.00 0.01 0.01          tau(i,j)
0.01 0.00 0.01
0.01 0.01 0.00

0.25 0.50 0.00          A(i,j)
0.25 0.25 0.50
0.15 0.15 0.30
```

Initial variable configuration in baseline scenario

```
42.667              cd
55.0                c
55.0                cprev
55.0                cprevprev
55.0                ctilde
1.0                 chi
1.0                 chibar
55.0                ltot
1.0                 w
1.0                 wprev

16.0                cdvec(i)
20.0
6.667

4.0                 crowvec(i)
5.0
3.333

0.35                lc(i)
0.10
0.20

0.35                lcrow(i)
0.10
0.20

35.0                l(i)
10.0
10.0


1.0                 pd(i)
1.0
1.0

1.0                 pdbar(i)
1.0
1.0

1.0                 prow(i)
1.0
1.0

1.0                 prowf(i)
1.0
1.0

1.0                 prowfbar(i)
1.0
1.0

0.02                rho(i)
0.02
0.02
```

```
0.02              rhoprev(i)
0.02
0.02

100.0             qd(i)
100.0
50.0

0.36363           s(i)
0.45455
0.18182

0.8               t(i)
0.8
0.6667

0.8               tprev(i)
0.8
0.6667

0.012             tz(i)
0.00667
0.013

0.012             tzprev(i)
0.00667
0.013

24.0              x(i)
20.0
13.333

2000.0            zrow(i)
3000.0
1000.0


0.2 0.4 0.0       Ad(i,j)
0.2 0.2 0.4
0.1 0.1 0.2

5.0 10.0 0.0      M
5.0  5.0 5.0
5.0  5.0 5.0
```