Globalization, Trade in Middle Products, and Relative Prices

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Abstract

As pointed out by Ronald W. Jones in a joint paper with Kalyan Sanyal (*American Economic Review*, 1982), most international trade is in raw materials and intermediate goods, and even most so-called endproducts that are traded must still transit through the production sector before reaching final demand. The recognition that nearly all international trade takes place in *middle products* – rather than in finished goods as it is assumed in most models of international trade theory – has some far reaching consequences for the measurement of real value added, real domestic income, and productivity. Besides being more realistic, the middle products approach also presents the major advantages that it is fully consistent with national accounts data and that it brings forward the role of a number of related, yet distinct, key price ratios: the terms of trade, the real exchange rate, and the trading gains. Given that most import and export decisions are made by firms, rather than by households, production theory, instead of consumer theory, is the appropriate setting for analyzing such issues as openness, trade imbalances and income distribution. This paper proposes a unified framework to address these issues and assesses the impact of changes in these price ratios on the external position of the United States.

Keywords: Globalization, middle products, imbalances, terms of trade, real exchange rate, trading gains, income distribution

JEL classification: F11, O47, C43, D33

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1. Introduction

Three ongoing trends that characterize the U.S. economy are receiving much attention of late, from economists, policy makers, and the public alike. Indeed, two of these were featured very prominently in the Spring 2007 issue of the International Monetary Fund's *World Economic Outlook*.[1] All three developments are thought to be linked, to some extent at least, to globalization and the increasing international fragmentation of production.[2] First, there is the falling income share of labor. As shown by Figure 1, U.S. labor income has fallen from close to 66% of total factor income to little more than 61% between 1970 and 2005.[3] Second, there is the remarkable increase in the openness of the U.S. economy. As depicted in Figure 2, the share of foreign trade in GDP has increased from about 5% in 1970 to over 13% in 2005.[4] And third, there is the large increase in the U.S. trade deficit. Whereas trade was still pretty much balanced as recently as the early 1990s, the deficit had grown to nearly 6% of GDP by 2005; see Figure 3.[5]

[Figure 1 about here]

[Figure 2 about here]

[Figure 3 about here]

The question of the distribution of income between labor and capital is usually analyzed from the standpoint of production theory. The declining labor share is then found to be mostly due to changes in relative factor endowments, technology, and the output mix, with the extent of the substitution possibilities between labor and capital playing a prominent role.

Analyses of openness and trade imbalances, on the other hand, are typically imbedded in consumer theory. The volumes of imports and exports are generally viewed as being demand determined, with (domestic, respectively foreign) income and relative prices playing a key role.[6] Advances in transportation, computing, and communication technologies, international transfers of technology, and lower trade barriers have led to significant reductions in the relative prices of imports, at home and abroad. This and the fact that many foreign made goods are perceived as superior (in the sense that their income elasticity of demand is greater than one) have had a marked impact on the volume of international trade, thereby explaining the increase in the global integration of the U.S. economy. As to the trade deficit that has developed

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[1] See International Monetary Fund (2007), Chapters 3 and 5.
[2] The term fragmentation of production was coined by Jones (2000).
[3] See the Appendix for a description of the data. The same phenomenon holds in many other industrialized countries; see International Monetary Fund (2007), Chapter 5.
[4] The foreign trade share is defined as the arithmetic average of the export and import shares (the latter in absolute value). The increasing trade integration of many countries has also been documented by the *World Economic Outlook* in the past; see International Monetary Fund (1997, 2002) for instance.
[5] While there are many other countries that register trade deficits, the U.S. deficit absorbs about three quarters of available world surpluses; see International Monetary Fund (2007), Chapter 3.
[6] This is the so-called *elasticity approach*; see Marquez (2000) for a good review.

over time, it is generally thought to be due to a real overvaluation of the U.S. dollar and to the relatively large income elasticity of the U.S. demand for foreign goods.[7]

Although large imbalances are not necessarily a cause for concern, for trade deficits and surpluses are simply a manifestation of intertemporal trade and there should be no presumption that this situation is suboptimal (the "consenting adults" view), the debate has nonetheless focused on the real exchange rate adjustment necessary to have a significant impact on trade balances.[8] As suggested by the standard open economy macro model (the Fleming-Mundell model) a real depreciation of the U.S. dollar would make U.S. exports more competitive on foreign markets and it would discourage imports.[9] One drawback of this type of analysis, though, is that, by being very Keynesian in spirit, it focuses almost exclusively on demand, with little regard for supply conditions. In a neoclassical setting, assuming that the home economy is small compared to the rest of the world, it may be adequate to assume that the foreign supply of imports is infinitely elastic, but then, by the same token, the foreign demand for the home product should probably be treated as infinitely elastic as well.[10] In other words, as far as exports are concerned it should be the domestic supply of exports, rather than the foreign demand for them, that matters. This suggests that production theory, rather than consumer theory, is the proper setting for explaining the volume of exports.

Another drawback of the Fleming-Mundell approach is that, given that there are only two goods in the model (a domestic one and a foreign one), it does not allow for the distinction between a country's real exchange rate and its terms of trade. The two terms are therefore often used interchangeably in the literature, even though they are really quite different concepts. Admittedly, standard neoclassical trade theory – such as the Heckscher-Ohlin-Samuelson (HOS) model – is not well equipped either to deal with exchange rate analysis, not even in the small open economy case. There is little place for the real exchange rate in that model, with a change in the relative price of exportables to importables meaning a change in the terms of trade, rather than in the exchange rate. The way a depreciation of the home currency might work in such a model is through absorption, thanks to a monetary channel: a depreciation of the home currency, by increasing the prices of both importables and exportables, will tend to reduce real balances and thus incite domestic households to save more and absorb less.

In order to be able to bring the real exchange rate into the analysis without adding a monetary sector one can add a third type of good, a nontradable good. A change in the real exchange rate can then be thought of as a change in the price of tradables relative to nontradables, without requiring any change in the price of exportables relative to importables (the terms of trade). A depreciation, by making tradable goods more expensive relative to nontradables, will encourage the production and discourage the absorption of tradables, thereby increasing net exports. For given factor endowments, the production (and hence absorption) of nontradables will necessarily decline. This adjustment mechanism is captured by the so-called

[7] The U.S. savings-investment imbalance is often also mentioned as a possible cause. However, in the context of the model developed in this paper, this is essentially another way to look at the exchange-rate mechanism: an increase in domestic absorption will, *ceteris paribus*, lead to an increase in the price of nontraded goods, which is equivalent to a real appreciation of the domestic currency.

[8] See Obstfeld and Rogoff (2004, 2005), for instance. The 2007 Spring edition of the IMF's *World Economic Outlook* (Chapter 3) is no exception.

[9] See Fleming (1962) and Mundell (1963).

[10] If the foreign demand for domestic exports were less than perfectly elastic, this would indicate that the home country has some market power, i.e. that it is not truly small.

Australian model, where the terms of trade are typically held constant, thereby making it possible to focus on the real exchange rate effect.[11]

Most theoretical international trade models, such as the HOS model and the specific factors model,[12] assume that trade takes place in final products. An improvement in the terms of trade is welfare enhancing because it allows the country to reach a higher social indifference curve,[13] even though real GDP (i.e. the position of the production possibilities frontier) does not change.[14] This hypothesis does not match the facts, however, since most international trade is in raw materials and nonfinished products. The international fragmentation of production, by making it possible for countries to exploit their comparative advantages even further at the component level, has accentuated this.[15] Furthermore, even most so-called finished products that are traded are not ready to meet final demand since they must still go through a number of domestic changes, such as unloading, storing, insuring, financing, repackaging, wholesaling, transporting, assembling, cleaning, advertising, retailing, and so on. The price that is charged to the final user is typically much higher than the price of the good when it first entered the country. The difference is accounted for by domestic value added.[16] If imports are to be treated as intermediate products, then the same must hold for exports since these must still be processed by foreign producers before being able to satisfy final demand. As such, exports are conceptually different from goods intended for the domestic market, which are essentially nontraded.[17] Trade thus takes place in middle products, to use the terminology of Sanyal and Jones (1982). It is a fact that most import decisions are made by firms, not by households. Thus, production theory, rather than consumer theory, would appear to be the proper setting to derive, not just the supply of exports as we argued earlier, but the demand for imports as well.[18] This also suggests that the three issues that were identified above – regarding the labor share, openness, and trade imbalances – are all related. In fact, as we shall see, the three shares can be derived jointly from the same optimization problem.

Treating traded goods as middle products also has far reaching consequences for the measurement of real value added, which we define as the real income realized from domestic production inclusive of trading gains. Indeed, in the HOS model trade is pictured as taking place almost as an afterthought, i.e. after production has been

[11] See Salter (1959), Dornbusch (1980), and Corden (1992), for instance.

[12] For the specific factors model, see Jones (1971).

[13] Some income redistribution might be needed for welfare to increase in the Pareto sense; see Krueger and Sonnenschein (1967) and Woodland (1982), for instance. Note that the impact of an improvement in the terms of trade on welfare and future growth may be ambiguous in the presence of distortions such as trade and production taxes or subsidies, in case of departures from perfect competition in the products or factor markets, or under uncertainty; see Pattanaik (1970), Batra and Scully (1971), and Lahiri and Sheen (1990), for instance.

[14] Note, however, that if real GDP is computed as a Laspeyres quantity index, as it is often the case, real GDP will tend to fall, irrespective of whether the terms of trade improve or worsen, whereas a Paasche index of real GDP would necessarily register an increase; see Kohli (1983). If real GDP is computed using a functional form that is exact for the underlying technology, real GDP will remain unchanged.

[15] See Obstfeld (2002).

[16] The same is true for re-exports (entrepot trade), which typically contain a substantial proportion of domestic value added; see Hanson and Feenstra (2004), for instance.

[17] Needless to say, nontraded goods may contain traded components to various degrees, just like exports may contain traded as well as nontraded elements; see Burstein, Eichenbaum and Rebelo (2005a, 2005b) for instance.

[18] See Burgess (1974), Kohli (1978, 1991).

completed. Any gains from trade benefit households, but have little to do with production and output. If trade is modelled as taking place in middle products, then it must be true that trade takes place *during* the production process. It is then an intimate part of production, and the extra value that it generates must be taken into account when computing the economy's total value added. A change in the terms of trade or in the real exchange rate tends to affect real value added. In that sense, these are very similar to a technological change.[19] Real GDP is therefore no longer the appropriate measure of real value added. Instead, one should focus on real GDI, i.e. nominal GDP (or GDI) deflated by the price of domestic absorption.[20]

The purpose of this paper is to show how, using a real GDI function for the United States under the assumption that trade is in middle products, our measures for the labor income share, openness, and trade imbalances – as depicted in Figures 1 to 3 – can be derived and estimated jointly. Changes in these shares can be explained by changes in the terms of trade and the real exchange rate, together with changes in relative factor endowments and technological progress.[21] Our econometric estimates also make it possible to get a sense as to how large a change in the terms of trade and/or the real exchange rate would be necessary to make a significant dent into the U.S. trade deficit.

2. Real GDP, real GDI, and relative prices

Trade in middle products means that trade must be modelled as part of the production process, rather than as taking place after production has been completed. In the spirit of Sanyal and Jones (1982), let us assume that production involves two primary inputs – labor (*L*) and capital (*K*) – and that these are used together with imports (*M*) to produce two outputs, one intermediate output (*X*) that is exported and one final, nontraded good (*N*) that is absorbed domestically.[22] Let $x_{j,t}$ and $w_{j,t}$ denote the endowment and the rental price of factor *j* ($j \in \{K, L\}$) at time *t*, respectively. The price and the quantity of good *i* ($i \in \{N, X, M\}$) at time *t* are denoted $p_{i,t}$ and $q_{i,t}$.

We begin with some definitions, starting with nominal GDP (Π_t):

$$\Pi_t \equiv p_{N,t}q_{N,t} + p_{X,t}q_{X,t} - p_{M,t}q_{M,t} \quad (1)$$

[19] See Diewert and Morrison (1986), Kohli (1990, 2004a), and Feenstra *et al.* (2005).

[20] In a recent paper, Feenstra *et al.* (2004) draw a distinction between two measures of real GDP: an output side measure, which they denote by GDP^o, and an expenditure-side measure, which they denote by GDP^e. The former is obtained by deflating nominal GDP by a price index for output (the usual GDP deflator), while the latter is obtained by using instead a price index for expenditures (a domestic absorption price index). The distinction between GDP^o and GDP^e is thus essentially the same as between real GDP and real GDI.

[21] We use the term "technological progress" in a broad sense: it includes technological advances in the production of goods and services as well as improvements in institutions and enhancements in economic (including trade) policies.

[22] This good can be thought of as an aggregate of consumption, investment and government purchases. The Sanyal and Jones model is somewhat more general in that it allows for two nontraded goods. On the other hand, the production structure it stipulates, by containing many elements of nonjointness and disjointness, is quite restrictive; see Kohli (2001a).

Let $p_{Y,t}$ be the price of GDP. We measure it as a Törnqvist chained price index:[23]

(2) $$p_{Y,t} \equiv p_{Y,t-1} \cdot \exp\left[\sum_i \pm \frac{1}{2}(s_{i,t} + s_{i,t-1}) \ln \frac{p_{i,t}}{p_{i,t-1}}\right] , \quad i \in \{N, X, M\} ,$$

where the sign is negative for imports and positive otherwise, and $s_{i,t}$ is the GDP share of component *i*:

(3) $$s_{i,t} \equiv \frac{p_{i,t} q_{i,t}}{\Pi_t} , \quad i \in \{N, X, M\} .$$

Real GDP ($q_{Y,t}$) can then be obtained by deflation:[24]

(4) $$q_{Y,t} \equiv \frac{\Pi_t}{p_{Y,t}} .$$

Real gross domestic income (real GDI, $q_{Z,t}$), on the other hand, can be obtained by deflating nominal GDP by the price of domestic absorption:

(5) $$q_{Z,t} \equiv \frac{\Pi_t}{p_{N,t}} .$$

As argued earlier, if trade is in middle products real GDI is a better measure of domestic real value added than real GDP, since the latter ignores the changes in real value added resulting from movements in the terms of trade and in the real exchange rate. The relationship between real GDI and real GDP is captured by κ_t, which is defined as:

(6) $$\kappa_t \equiv \frac{q_{Z,t}}{q_{Y,t}} .$$

κ_t can be thought of as an index of the trading gains; see Kohli (2006). Its path is depicted in Figure 4. The trading gains index fell significantly during the 1970s, from 1.00 to about 0.965. This means that real GDP overestimated the growth of U.S. real value added by about 3.5% over the course of that decade. After recovering somewhat during the early 1980s, the index has mostly moved sideways. Nonetheless, there were individual years when the trading gains or losses were non-trivial, such as in 1987, when real GDP growth overestimated the growth in real value added by about 0.3%, or in 1998 and 2001, when it underestimated it by about 0.4%.

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[23] Like for other price indices, the base period price (e.g. the price of period 0, $p_{Y,0}$) is typically set to unity.

[24] Real GDP so defined has the implicit Törnqvist form; see Kohli (2004b). It is a superlative index in the sense of Diewert (1976).

[Figure 4 about here]

We next define the price of traded goods ($p_{T,t}$) as the geometric mean of the prices of exports and imports:

$$(7) \qquad p_{T,t} \equiv p_{X,t}^{\;1/2} p_{M,t}^{\;1/2} \;.$$

We can now identify several important price ratios that will be relevant for the analysis that follows. We begin with the real exchange rate (ε_t), also known as the Salter ratio, which is defined as the relative price of traded vs. nontraded goods:[25]

$$(8) \qquad \varepsilon_t \equiv \frac{p_{T,t}}{p_{N,t}} \;.$$

Note that the real exchange rate so defined does not coincide exactly with another common definition of the real exchange rate (sometimes called the PPP real exchange rate), namely the nominal exchange rate adjusted for price level differentials.[26] To see this, let $p^*_{N,t}$ be the price of foreign absorption (expressed in foreign currency) and let E_t be the nominal exchange rate (the price of foreign exchange). The PPP (nominal) exchange rate can then be defined as:

$$(9) \qquad \pi_t \equiv \frac{p_{N,t}}{p^*_{N,t}} \;,$$

whereas the PPP real exchange rate can be written as:

$$(10) \qquad e_t \equiv \frac{E_t \, p^*_{N,t}}{p_{N,t}} = \frac{E_t}{\pi_t} \;.$$

Comparing (8) with (10), the difference between ε_t and e_t is obvious: the former refers to the domestic prices of traded and nontraded goods, whereas the latter makes an international comparison between the prices of nontraded goods. As we shall see below, neither π_t nor e_t are relevant for domestic production decisions.[27]

Next, we consider the terms of trade (τ_t), defined as the price of exports relative to the price of imports:

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[25] See Salter (1959), Dornbusch (1980), Frenkel and Mussa (1984), Corden (1992), and the literature on the Australian model. An increase in ε signals a real depreciation of the home currency.

[26] See Edwards (1989) for a review of competing definitions of the real exchange rate.

[27] Note that in the absence of transportation costs and of any barriers to trade, one would expect the law of one price to hold: $p_{T,t} = E_t \, p^*_{T,t}$. In that case, the PPP real exchange rate can also be expressed as $e_t = \varepsilon_t / \varepsilon^*_t$, where $\varepsilon^*_t \equiv p^*_{T,t} / p^*_{N,t}$ is the foreign Salter ratio; ε^*_t plays no role in our analysis.

(11) $$\tau_t \equiv \frac{p_{X,t}}{p_{M,t}} \ .$$

The paths of ε_t and τ_t are depicted in Figure 5. It is striking that over the last 25 years ε_t has fallen substantially, by over 40%. That is, the price of traded goods has increased much less rapidly than the price of nontraded goods. This amounts to a substantial real appreciation of the U.S. dollar. Without wanting to draw any definite conclusions at this stage, the fall in the real exchange rate might help to explain why U.S. production has tilted towards the production of nontraded goods and away from the production of traded goods, whereas absorption has done exactly the reverse, thereby leaving a large gap between the production and the absorption of traded goods. The figure also shows the terms of trade. Its path is clearly distinct from that of the real exchange rate. The U.S. terms of trade have been fairly steady over the past 25 years. They did deteriorate significantly during the 1970s following the two oil shocks, thereby reducing real GDI at that time.

[Figure 5 about here]

We may note from (4) and (5) that κ_t as defined by (6) can also be expressed as a price ratio, namely the price of GDP relative to the price of domestic absorption:

(12) $$\kappa_t = \frac{p_{Y,t}}{p_{N,t}} \ .$$

It is noteworthy that ε_t, τ_t and κ_t are not fully independent of each other. Indeed, definitions (7), (8) and (11) imply that:

(13) $$\frac{p_{X,t}}{p_{N,t}} = \varepsilon_t \, \tau_t^{1/2}$$

(14) $$\frac{p_{M,t}}{p_{N,t}} = \varepsilon_t \, \tau_t^{-1/2} \ .$$

It thus follows from (2) and (12) that:

(15) $$\kappa_t = \kappa_{t-1} \cdot \exp\left[\frac{1}{2}(s_{A,t} + s_{A,t-1}) \ln \frac{\tau_t}{\tau_{t-1}} + \frac{1}{2}(s_{B,t} + s_{B,t-1}) \ln \frac{\varepsilon_t}{\varepsilon_{t-1}} \right] ,$$

where $s_{A,t} \equiv (s_{X,t} + s_{M,t})/2$ is the average foreign trade share (the measure of openness depicted in Figure 2) and $s_{B,t} \equiv s_{X,t} - s_{M,t}$ is the trade balance relative to GDP as shown in Figure 3. Expression (15) provides a convenient decomposition of the trading gains into a terms of trade effect and a real exchange rate effect.[28] This is shown in Figure 4, using 1970 as a reference period. It can be seen that the real exchange rate effect has been slightly positive over the entire period. Indeed, the drop in the (relative) price of tradables has had a positive income effect given that the U.S. trade account was in a deficit position for most of the period: the fall in export revenues has been more than compensated by the reduction in the import bill. The terms of trade effect, on the other hand, has been negative on balance.

3. Description of the aggregate technology

Let Ψ_t be the production possibilities set (i.e. the set of all feasible input and output combinations) at time *t*.[29] We assume that Ψ_t is a convex cone. An illustration of such a technology, drawn in the nontraded good, exports, and import quantity space, for three different levels of domestic factor endowments, is shown in Figure 6.[30]

[Figure 6 about here]

The aggregate technology can then be described by a real GDI function defined as:[31]

$$(16) \qquad q_{Z,t} = z(\tau_t, \varepsilon_t, x_{K,t}, x_{L,t}, t) \equiv \max_{q_N, q_X, q_M} \left\{ \begin{matrix} q_N + \varepsilon_t \tau_t^{1/2} q_X - \varepsilon_t \tau_t^{-1/2} q_M : \\ (q_N, q_X, q_M, x_{K,t}, x_{L,t}) \in \Psi_t \end{matrix} \right\} .$$

One can show that the real GDI function has the following slope properties:[32]

$$(17) \qquad \frac{\partial z(\cdot)}{\partial \tau} = \frac{1}{2} \frac{\varepsilon_t}{\tau_t} (\tau_t^{1/2} q_{X,t} + \tau_t^{-1/2} q_{M,t})$$

$$(18) \qquad \frac{\partial z(\cdot)}{\partial \varepsilon} = \tau_t^{1/2} q_{X,t} - \tau_t^{-1/2} q_{M,t}$$

$$(19) \qquad \frac{\partial z(\cdot)}{\partial x_K} = \frac{w_{K,t}}{p_{N,t}}$$

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[28] See Kohli (2008b). The terms of trade effect defined by the first term in the square brackets of (15) does not coincide exactly with the terms of trade effect as defined by Diewert and Morrison (1986) and Kohli (1990); see Kohli (2006) for details.

[29] Throughout this paper we assume that resources are fully employed and freely mobile between activities.

[30] For the purpose of this illustration the transformation function $\psi(\cdot)$ has been assumed to be as follows: $\psi(q_N, q_X, q_M, x) = (q_N^2 + q_X^2) - q_M x = 0$ where x is an aggregate of labour and capital, and it takes on the values of $2/3$, 1, and 2. For simplicity, we have thus assumed that the technology is globally separable (i) between the domestic factors and the three products, and (ii) between the composite domestic factor and imports, on one hand, and exports and nontraded goods, on the other hand. These restrictions are not imposed in our empirical work.

[31] The real GDI function can be viewed as a modified nominal GDP function; see Kohli (1978, 1991, 2004a, 2007), Woodland (1982), Harrigan (1997).

[32] See Kohli (2007).

(20) $$\frac{\partial z(\cdot)}{\partial x_L} = \frac{w_{L,t}}{p_{N,t}}$$

(21) $$\frac{\partial z(\cdot)}{\partial t} = \mu_t q_{Z,t} \ ,$$

where μ_t is the instantaneous rate of technological change.

For the empirical implementation we need a functional form to describe (16). One form well suited for our purposes is the Translog function.[33] It provides a second-order approximation in logarithms of an arbitrary real GDI function:

(22) $$\begin{aligned} \ln q_{Z,t} = {} & \ln x_{L,t} + \alpha_0 + \alpha_\tau \ln \tau_t + \alpha_\varepsilon \ln \varepsilon_t + \beta_K \ln k_t + \beta_T t \\ & + \frac{1}{2}\gamma_{\tau\tau} \ln \tau_t{}^2 + \gamma_{\tau\varepsilon} \ln \tau_t \ln \varepsilon_t + \frac{1}{2}\gamma_{\varepsilon\varepsilon} \ln \varepsilon_t{}^2 \\ & + \frac{1}{2}\phi_{KK} \ln k_t{}^2 + \phi_{KT} \ln k_t \, t + \frac{1}{2}\phi_{TT} \, t^2 \\ & + \delta_{\tau K} \ln \tau_t \ln k_t + \delta_{\varepsilon K} \ln \varepsilon_t \ln k_t + \delta_{\tau T} \ln \tau_t \, t + \delta_{\varepsilon T} \ln \varepsilon_t \, t \end{aligned}$$

where k_t is the capital/labor ratio:

(23) $$k_t \equiv \frac{x_{K,t}}{x_{L,t}} \ .$$

In the case of (22) the first-order conditions (17)-(21) can best be expressed in share form through logarithmic differentiation:

(24) $$s_{A,t} = \alpha_\tau + \gamma_{\tau\tau} \ln \tau_t + \gamma_{\tau\varepsilon} \ln \varepsilon_t + \delta_{\tau K} \ln k_t + \delta_{\tau T} t$$

(25) $$s_{B,t} = \alpha_\varepsilon + \gamma_{\tau\varepsilon} \ln \tau_t + \gamma_{\varepsilon\varepsilon} \ln \varepsilon_t + \delta_{\varepsilon K} \ln k_t + \delta_{\varepsilon T} t$$

(26) $$s_{K,t} = \beta_K + \delta_{\tau K} \ln \tau_t + \delta_{\varepsilon K} \ln \varepsilon_t + \phi_{KK} \ln k_t + \phi_{KT} t$$

(27) $$s_{L,t} = 1 - \beta_K - \delta_{\tau K} \ln \tau_t - \delta_{\varepsilon K} \ln \varepsilon_t - \phi_{KK} \ln k_t - \phi_{KT} t$$

(28) $$\mu_t = \beta_T + \delta_{\tau T} \ln \tau_t + \delta_{\varepsilon T} \ln \varepsilon_t + \phi_{KT} \ln k_t + \phi_{TT} t \ .$$

Before turning to the estimation of the model, we must note that one of (26) and (27) is superfluous, since the two factor shares add up to unity. Note also that μ_t is not directly observable. In what follows, we will adopt the procedure of Kohli (1991) and approximate μ_t by the average rate of total factor productivity between period *t-1* and *t+1*. The system of equations (24)–(25) and (27)–(28) is estimated together with the real GDI function (22) itself. Note that the three equations (24), (25) and (27) directly yield the three variables that were flagged in the introduction, namely openness, the trade balance and the labor share. According to our model all

[33] See Christensen, Jorgenson, and Lau (1973), Diewert (1974), Kohli (1978, 1991, 2004a).

three are functions of the real exchange rate, the terms of trade, the capital/labor ratio and the passage of time.

As indicated by (24)–(28), and as to be expected from neoclassical trade theory, domestic relative factor endowments do matter as well. The U.S. capital-labor ratio has been increasing substantially over time, increasing by over 50% between 1970 and 2005; see Figure 7. Yet, the capital intensity variable has often been ignored in the current debate about globalization, trade imbalances, and income distribution.

[Figure 7 about here]

It should be noted that Sanyal and Jones (1982) made quite explicit assumptions about the production structure of their model, i.e. about the way inputs are transformed into outputs. Their model contained many elements of nonjointness and disjointness in production. Such hypotheses often lead to strong and unambiguous comparative statics results, but they also severely restricts the flexibility of the technology. Our model does not rely on any such restrictions: real GDI function (22) is fully flexible and perfectly compatible with joint production.[34]

4. Estimation results

The model was first estimated by iterative Zellner (IZEF) as implemented in TSP, version 4.3A. The parameter estimates are reported in the first column of Table 1, together with their t-values. It can be seen that most parameters are determined with a relatively high degree of precision. We also verified that these estimates satisfy all required regularity (curvature and monotonicity) conditions for all observations. Conventional R^2's for the five equations are reported at the bottom of the table, but these must be interpreted with care since they are not derived from ordinary least squares estimates. The goodness of fit seems particularly low for the technological change equation, but this is quite typical, since, as shown by (38) and (39) below, the dependent variable consists of an underlying rate of technological progress – that is quite steady over time – and a random element.[35]

[Table 1 about here]

Although we assume that relative output prices and domestic factor endowments are exogenous to production decisions, this is unlikely to be true in an econometric sense in the case of the United States given its size, and in view of the fact that consumption/savings decisions by households are likely to affect the price of nontraded goods. We have therefore reestimated the model by iterative three stage least squares (I3SLS). The instruments that we have used are: the lagged values of the terms of trade and of the real exchange rate, the domestic factor endowments, the government purchases of goods and services (all of these in logarithms), the government budget deficit, the federal funds rate, the unemployment rate, time, time squared, and a constant term. The resulting parameters are shown in the second column of Table 1. We have verified that these estimates too fulfil all regularity conditions for all observations.

[34] See Kohli (2001a, 2001b) for an empirical implementation and a test of the restrictions imposed by the Sanyal and Jones production structure.
[35] See Kohli (1991) for a similar result.

Looking at share equations (24), (25) and (27), we find that an improvement in the terms of trade (a rise in τ_t) tends to favour openness, improve the trade balance, and increase the income share of labor. The same holds true for a real depreciation of the currency (an increase in ε_t). An increase in capital intensity (an increase in k_t) also leads to an increase in the labor share,[36] but it tends to hinder openness and worsen the trade balance. Technological change (the passage of time), finally, favours openness and tends to improve the trade account, but it is biased against labor.

Before examining what light our estimates might shed on the recent experience of the United States in terms of openness, trade imbalances and income distribution, it is worthwhile computing the standard price and quantity elasticities that our production model allows us to identify.[37] 2005 values (I3SLS estimates) are reported in expression (29):

$$(29)\quad \begin{bmatrix} d\ln q_X \\ d\ln q_M \\ d\ln q_N \\ d\ln w_K \\ d\ln w_L \\ d\mu \end{bmatrix} = \begin{bmatrix} 1.168 & -0.802 & -0.366 & -0.807 & 1.807 & 0.063 \\ 0.612 & -1.124 & 0.512 & -0.245 & 1.245 & 0.044 \\ -0.039 & -0.072 & 0.112 & 0.414 & 0.586 & 0.012 \\ -0.240 & 0.095 & 1.146 & -0.846 & 0.846 & 0.015 \\ 0.322 & -0.291 & 0.969 & 0.507 & -0.507 & 0.012 \\ 0.006 & -0.005 & -0.001 & 0.001 & -0.001 & 0.000 \end{bmatrix} \begin{bmatrix} d\ln p_X \\ d\ln p_M \\ d\ln p_N \\ d\ln x_K \\ d\ln x_L \\ dt \end{bmatrix}$$

Each entry of the square matrix can be viewed as the partial derivative of one of the six endogenous variables with respect to one of the six exogenous variables. Thus, the first entry in the north-east corner (1.168) is the own price elasticity of the supply of exports, $\partial\ln q_X / \partial\ln p_X$. We can see that the own price elasticities of the supply of exports and of the demand for imports are both greater than one in absolute value. Looking at the cross price elasticities of output supply, we find that an increase in the price of exports discourages the production of nontradables, but it has a stimulating effect on the demand for imports. Similarly, an increase in the price of nontradables also encourages imports, and it shifts resources away from the production of exports. An increase in the price of imports has a negative impact on the production of both exports and nontradables. The inverse price elasticities of the demand for labor and for capital (rows and columns 4–5) show that an increase in the endowment of either factor depresses its own rental price by a small amount and favour the other factor. The implied value for the Hicksian elasticity of complementarity between labor and capital is 1.353. Of considerable interest also are the Stolper-Samuelson elasticities (rows 4 and 5, columns 1 to 3). They show that an increase in export prices and a drop in import prices heavily favour labor at the expense of capital, and that an increase in the price of nontradables leads to an increase in the nominal rental price of both factors, although in real terms it makes labor slightly worse off. The Rybczynski elasticities (rows 1-3, columns 4-5) convey the same message translated into the quantity space: an increase in the endowment of labor heavily favours foreign trade,

[36] This is the manifestation of a Hicksian elasticity of complementarity between capital and labour that is greater than one: its estimate oscillates between 1.35 and 1.37 over the sample period.
[37] See Kohli (1978, 1991) for further explanations, and Kohli (2004a) for the link between a real GDI function and a nominal GDP function.

whereas an increase in the capital stock, other things equal, actually reduces the supply of exports and the demand for imports. The last column of the square matrix shows that technological change has a positive impact on the demand for imports and on the supply of exports and nontradables (although it is biased in favour of foreign trade) and that, although it benefits both factors, it is biased in favour of capital. The last row, finally, indicates that an improvement in the terms of trade or an increase in the capital-labor ratio stimulate technological change.

5. Accounting for changes in openness, imbalances, and income shares

As time passes, technological progress and changes in relative factor endowments shift the production possibilities frontier. To the extent that the shift is non-neutral, the input-output mix would change even if relative prices did not. Of course, over time relative prices (the terms of trade and the real exchange rate) will tend to change too: this leads to further changes in the input-output mix, as the production point moves along the production possibilities frontier. The changes in openness, in the trade balance and in the labor share that we observe over time reflect the summation of these four effects. To disentangle these forces, we can take the first differences of equations (24), (25) and (27):

(30) $$\Delta s_{A,t} = \hat{\gamma}_{\tau\tau}\Delta\ln\tau_t + \hat{\gamma}_{\tau\varepsilon}\Delta\ln\varepsilon_t + \hat{\delta}_{\tau K}\Delta\ln k_t + \hat{\delta}_{\tau T} + u_{A,t}$$

(31) $$\Delta s_{B,t} = \hat{\gamma}_{\varepsilon\tau}\Delta\ln\tau_t + \hat{\gamma}_{\varepsilon\varepsilon}\Delta\ln\varepsilon_t + \hat{\delta}_{\varepsilon K}\Delta\ln k_t + \hat{\delta}_{\varepsilon T} + u_{B,t}$$

(32) $$\Delta s_{L,t} = -\hat{\delta}_{\tau K}\Delta\ln\tau_t - \hat{\delta}_{\varepsilon K}\Delta\ln\varepsilon_t - \hat{\phi}_{KK}\Delta\ln k_t - \hat{\phi}_{KT} + u_{L,t} \ ,$$

where Δ is the first difference operator, the hats (^) signal estimated values, and the *u*'s denote unexplained residuals.

Our results for the period 1970–2005 are summarized in Table 2. As was already illustrated by Figure 1, openness increased substantially over the time period, by about 7.8 percentage points relative to GDP. This increase is due exclusively to technological progress, for the increase in capital intensity, the worsening in the terms of trade, and the real appreciation of the currency all three pushed in the opposite direction. Technological progress typically leads to an outward shift in the production possibilities frontier. Our results indicate that in the U.S. case, this shift is biased, i.e. it is accompanied by a twist that favours the production of exports and the use of imports over the production of nontraded goods.[38]

[Table 2 about here]

As to the deterioration of the trade balance (about 6.1 percentage points over the time interval), it is mostly due to the worsening of the terms of trade, followed by the increase in U.S. capital intensity and the real appreciation of the currency. The increase in capital intensity led to a twist in the production possibilities that, for given relative prices, heavily favoured the production of nontraded goods as the expense of exports; see the elasticity estimates contained in (29). The demand for imports was penalized as well, but much less so than the supply of exports. Far from being offset

[38] This is confirmed by the estimates of $\partial\ln q_X/\partial t$, $\partial\ln q_M/\partial t$, and $\partial\ln q_N/\partial t$ reported in (29).

by changes in relative prices, this change in the input-output mix was actually reinforced by the worsening in the terms of trade and the fall in the relative price of traded goods. Technological change had a substantial effect too, but it acted in the opposite direction. It must be noted, though, that about one third of the deterioration of the trade balance cannot be explained by the model.

With regards to the labor share, finally, the observed 4.3 percentage point fall is explained mostly by the worsening in the terms of trade and by technological change. The real appreciation that took place had a small negative effect only. The increase in capital intensity, on the other hand, contributed to contain the fall in the labor share. If it were not for that positive influence, the fall in the labor share would have been nearly twice as high. The negative impact that the worsening in the terms of trade had on the labor share can probably best be understood by considering the complementarity relationship (in the Hicksian sense) that exists between imports and labor: if the use of imports is curtailed as the result of the increase in their relative price, it impacts negatively on the marginal product of labor. Admittedly about one third of the fall in the income share of labor is not accounted for by the model.

In summary, the worsening in the United States's terms of trade followed by the increase in capital intensity that appears to be biased in favour of the production of nontradables appear to be the main reasons for the deterioration in the trade account. Technological change, on the other hand, favours net exports and openness. As for labor, capital is its best friend. An improvement in the terms of trade would also do much to lift the labor share.

What would it take to make a significant dent into the U.S. trade deficit? According to the estimates reported in Table 1, column 2, it would require a 9.0% real depreciation (i.e. an increase in the relative price of traded goods) to reduce the deficit relative to GDP by one percentage point. It would take a 11.3% improvement in the U.S. terms of trade to achieve the same result. A joint 10% real depreciation and 10% improvement in the terms of trade would reduce the deficit by 1.9 percentage points.[39] This would also increase openness by about 2.0 percentage points and raise the labor share by 1.5 percentage points. Over time, regarding the offsetting influences of capital accumulation and technological change on the trade balance and the labor share, it would take increases in the capital-labor ratio at rates between 0.6% and 2.4% (vs. the historical average of 1.3%) to increase both shares.

6. Productivity

As we have seen, the view that all trade takes place in middle products has profound implications for the measurement of real value added. It should therefore come as no surprise that it also has significant consequences for the measurement of productivity, in particular the measurement of average labor productivity.[40] Indeed, the appropriate numerator should be real GDI rather than real GDP when measuring real value added per unit of labor. Let $\Theta_{t,t-1}$ be the index of average labor productivity between times *t-1* and *t*:

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[39] For a given price of nontraded goods, this would require import prices to increase by 4.9% and export prices to increase by 15.4%.

[40] For an analysis of the relationship between the average and the marginal measures of labour productivity, see Kohli (2008a).

(33) $$\Theta_{t,t-1} \equiv \frac{q_{Z,t} / x_{L,t}}{q_{Z,t-1} / x_{L,t-1}} \ .$$

Real GDI function (22) provides a natural starting point for our analysis. Substracting $\ln x_{L,t}$ from both sides of (22), taking first-order differences, and making use of (24)–(28) we get:

(34) $$\Theta_{t,t-1} = \Theta^{\tau}_{t,t-1} \cdot \Theta^{\varepsilon}_{t,t-1} \cdot \Theta^{k}_{t,t-1} \cdot \Theta^{T}_{t,t-1} \cdot \Theta^{u}_{t,t-1} \ ,$$

where:

(35) $$\Theta^{\tau}_{t,t-1} \equiv \exp\left[\frac{1}{2}(\hat{s}_{A,t} + \hat{s}_{A,t-1}) \ln \frac{\tau_t}{\tau_{t-1}}\right]$$

(36) $$\Theta^{\varepsilon}_{t,t-1} \equiv \exp\left[\frac{1}{2}(\hat{s}_{B,t} + \hat{s}_{B,t-1}) \ln \frac{\varepsilon_t}{\varepsilon_{t-1}}\right]$$

(37) $$\Theta^{k}_{t,t-1} \equiv \exp\left[\frac{1}{2}(\hat{s}_{K,t} + \hat{s}_{K,t-1}) \ln \frac{k_t}{k_{t-1}}\right]$$

(38) $$\Theta^{T}_{t,t-1} \equiv \exp\left[\frac{1}{2}(\hat{\mu}_t + \hat{\mu}_{t-1})\right]$$

(39) $$\Theta^{u}_{t,t-1} \equiv \frac{q_{Z,t} / q_{Z,t-1}}{\hat{q}_{Z,t} / \hat{q}_{Z,t-1}} \ .$$

The hats (^) in (35)–(39) denote fitted – as opposed to observed – values. The growth in average labor productivity can thus be decomposed into five terms: the contributions of changes in the terms of trade, in the real exchange rate and in capital intensity, the effect of technological progress, and an unexplained residual. The first two terms together account for the trading gains; see expression (15). The last two terms together capture the full change in total factor productivity (TFP): it consists of an underlying, persistent term ($\Theta^{T}_{t,t-1}$) and of an unexplained, random residual ($\Theta^{u}_{t,t-1}$). Note that (35)–(37) could also be computed on the basis of observed rather than fitted shares. In that case TFP would have to be computed as a residual, however, and it would not be possible to distinguish between $\Theta^{T}_{t,t-1}$ and $\Theta^{u}_{t,t-1}$.[41]

Decomposition (34) is documented by Figure 8 that shows the cumulated sums of these effects. The lowest line (denoted TG) represents the trading gains.[42] For the second line up (TG & KL) we have added the capital intensity effect, and then, for the third line (TG & KL & TC), the technological change effect. Adding finally the unexplained component one obtains the observed labor productivity line (denoted

[41] Note that, in any case, TFP is a catch-all term: it includes the effects of technological progress, changes in institutions, adjustments in policy, and so on. It is not possible to assess the relative importance of each one of these factors.

[42] In order not to overburden the graph, we do not represent the terms of trade effect and the real exchange rate effect separately. The decomposition of the trading gains was shown in Figure 4. Note, however, that the decomposition shown in Figure 4 was based on observed rather than fitted shares, but the difference is numerically very small.

QZ/XL). One sees that average labor productivity has increased by nearly 70% over the sample period. Technological change was clearly the driving force, with the increase in capital intensity nonetheless responsible for close to one third of the increase. As indicated earlier, the trading gains have been negative on average, holding back average labor productivity by about 2.5%.

[Figure 8 about here]

7. Conclusions

Ron Jones's insight that most trade is in middle products has far reaching consequences for the measurement of real value added and productivity, and for the modeling of international trade. It implies that production theory is the proper setting for the analysis of issues such as openness, trade imbalances, and income distribution, and that certain key ratios, such as the terms of trade, the price of traded vs. nontraded goods, and capital intensity are the driving forces. It also suggests that the emphasis on the PPP real exchange rate, which compares the prices of final goods at home and abroad, might be misplaced.

Our empirical results indicate that technological change has been a major force in the changes that have taken place in recent decades, be it in terms of openness, trade imbalances, or income distribution. The observed increase in the average productivity of labor, itself, has been largely driven by the growth in TFP.

Our results also suggest that a large increase in the relative price of traded goods is likely to be required to make a significant dent into the U.S. trade deficit. Ideally, the increase in export prices should exceed the increase in import prices, thereby also improving the U.S. terms of trade. This would not only alleviate some of the anxieties regarding the large trade deficit, but it would also be beneficial to the United States from a welfare perspective. Thus, a 15% increase in export prices accompanied by a 5% rise in import prices would reduce the deficit by about two percentage points. Admittedly, these calculations should only be viewed as rough estimates, but they do suggest that a sizable increase in the traded to nontraded good price ratio would be required for the U.S. current account deficit to shrink significantly. A drop in nontraded service prices and in housing prices could contribute to the adjustment.

Admittedly, the model has nothing to say about the causes of the changes in the terms of trade and the real exchange rate, and what kind of shock, if any, would trigger an adjustment. Without doubt, the observed changes in relative prices reflect shifts in world demand and supply conditions, factor endowments, technology, tastes, demography, and so on. One should not necessarily think in terms of causality either, for in a general equilibrium situation, prices and quantities are determined simultaneously. However, one might argue that more attention needs to be paid to the terms of trade and to the relative prices of traded and nontraded goods when analyzing issues related to globalization.

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Appendix: Description of the data

All data are annual for the period 1970 to 2005. The prices and quantities of all inputs and outputs are required. The data for GDP and its components, and the corresponding prices, are taken from the *Bureau of Economic Analysis* website. Quantities are then obtained by deflation. Data on the capital stock, labor compensation, and gross domestic factor income are also derived from *BEA* sources. The quantity of capital services is assumed to be proportional to the stock. Capital income is defined as gross domestic factor income minus labor compensation. The quantity of labor services is computed by multiplying the total number of employees on nonfarm payrolls by an index of the average number of weekly hours worked in the nonfarm business sector. Both these series are taken from the *Bureau of Labor Statistics* website. The user costs of labor and capital are then obtained by dividing labor and capital income by the corresponding quantity series. The price of nontradables is computed as a Törnqvist price index of the deflators of consumption, investment and government purchases. All output (including import) prices and both domestic input quantities are set to unity in 2000; t is defined as a time trend with unit annual increments, and it is set to zero for the year 2000.

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Figure 1

Figure 2

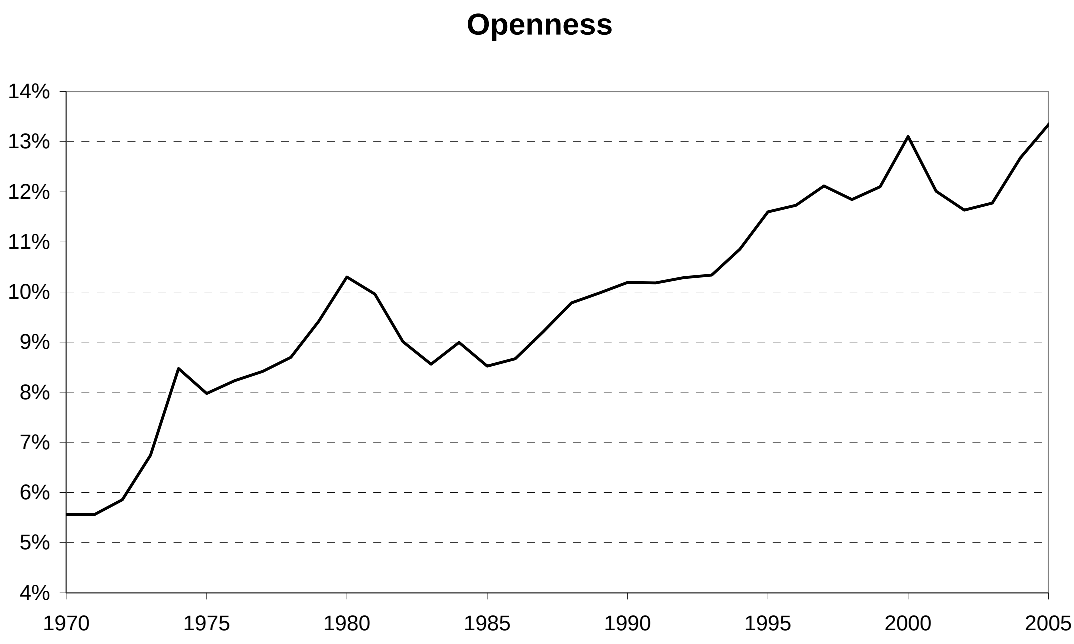

Figure3

Trade Balance

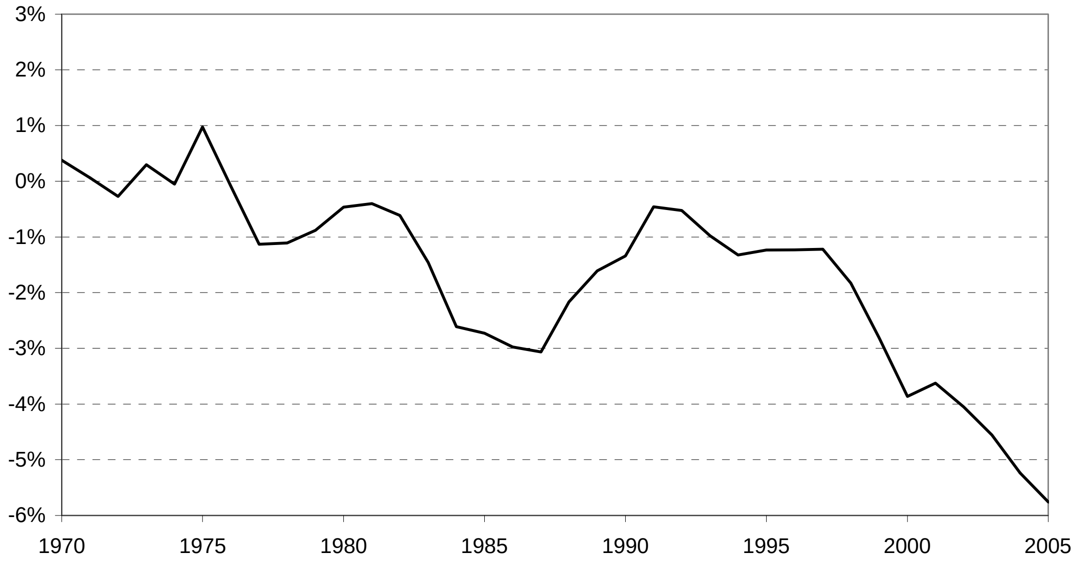

Figure 4

Trading Gains:
Terms of Trade and Real Exchange Rate Effects

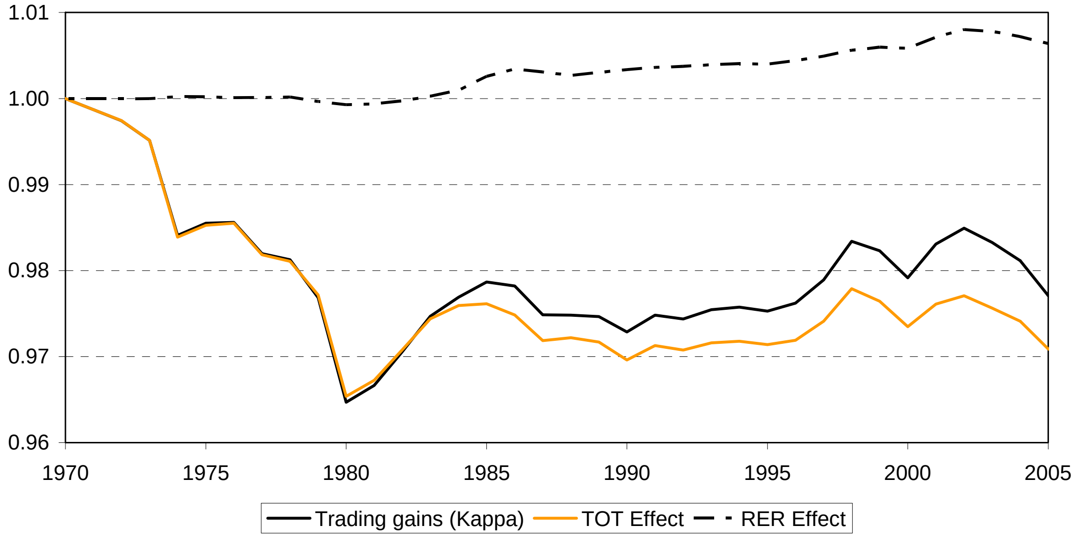

Figure 5

Terms of Trade and Real Exchange Rate

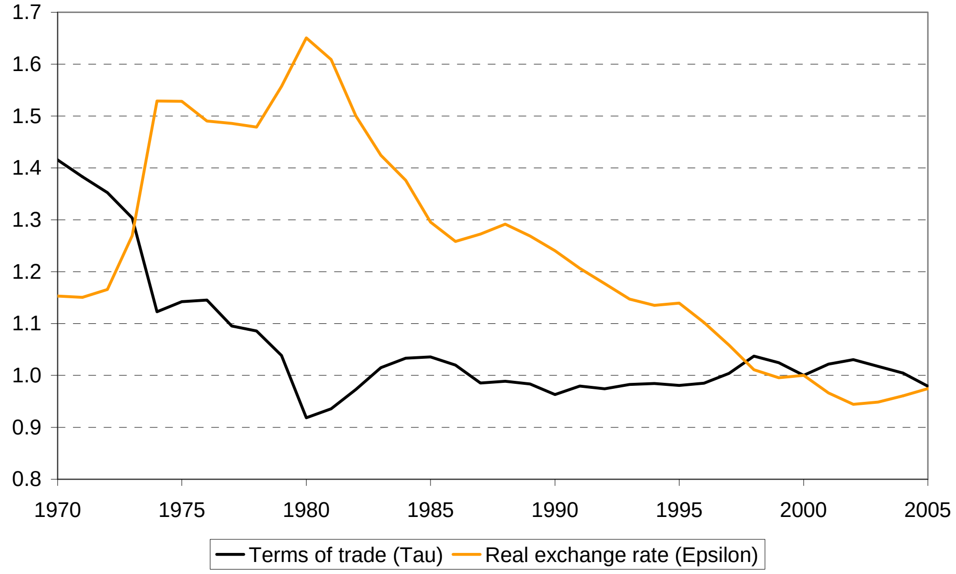

Figure 6

Three-Good Production Possibilities Surface for Alternative Domestic Factor Endowments

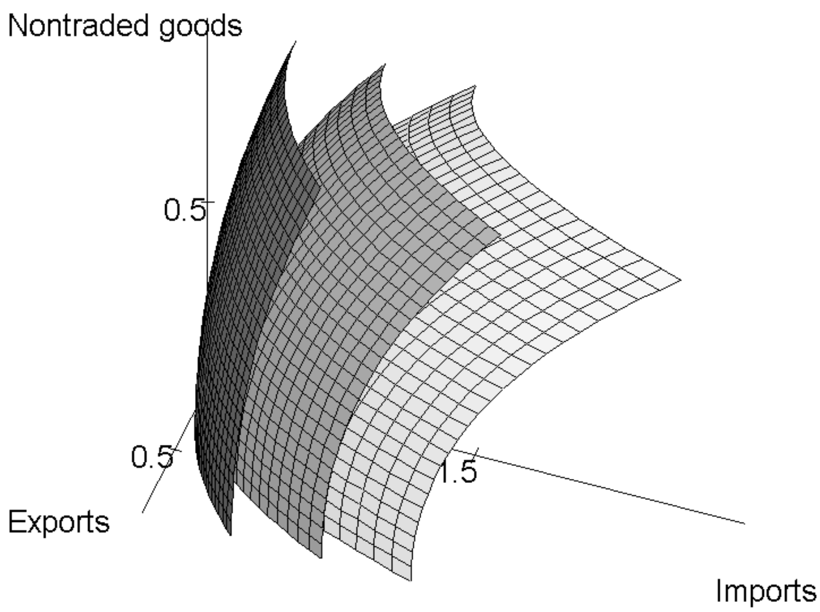

Figure 7

Capital-Labor Ratio

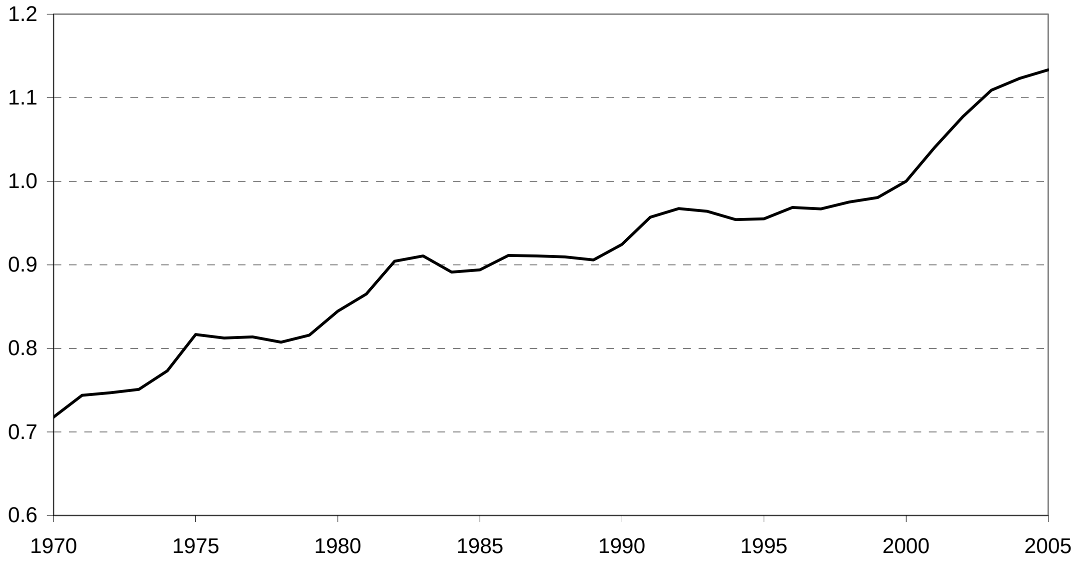

Figure 8

Average Labor Productivity

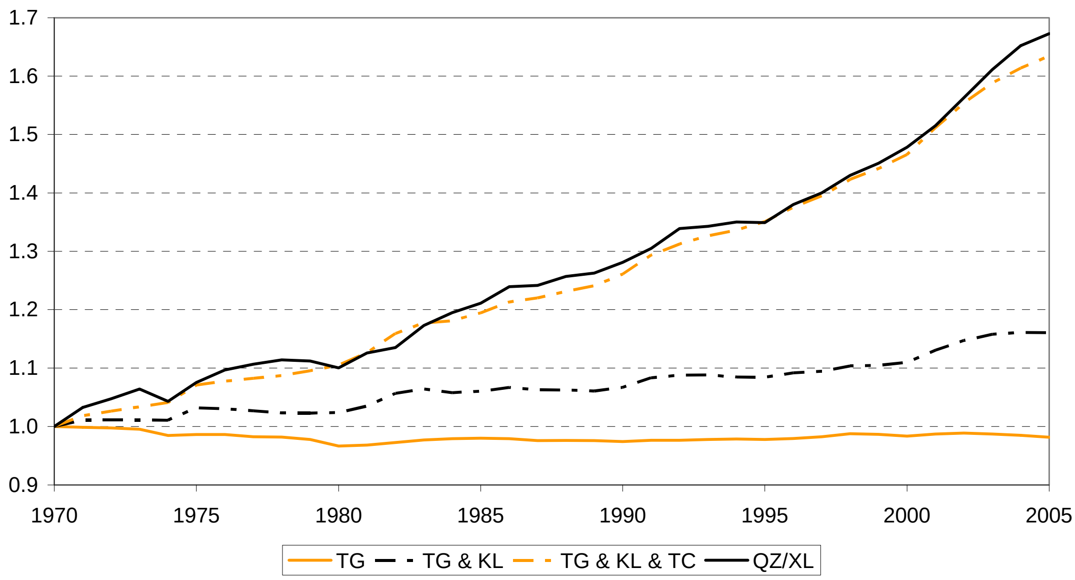

Table 1

Parameter Estimates
(t-values in parentheses)

	IZEF	*I3SLS*
$\hat{\alpha}_0$	9.19444	9.19405
	(3,363.00)	(3,356.97)
$\hat{\alpha}_\tau$	0.12147	0.12249
	(104.15)	(89.64)
$\hat{\alpha}_\varepsilon$	-0.03109	-0.03007
	(-10.47)	(-11.07)
$\hat{\beta}_K$	0.38055	0.37901
	(205.19)	(187.69)
$\hat{\gamma}_{\tau\tau}$	0.09513	0.09309
	(4.41)	(3.16)
$\hat{\gamma}_{\tau\varepsilon}$	0.11507	0.11630
	(6.87)	(5.28)
$\hat{\gamma}_{\varepsilon\varepsilon}$	0.07778	0.07972
	(3.74)	(3.74)
$\hat{\phi}_{KK}$	-0.13730	-0.08265
	(-4.03)	(-2.12)
$\hat{\delta}_{\tau K}$	-0.07940	-0.11114
	(-4.17)	(-5.01)
$\hat{\delta}_{\varepsilon K}$	-0.01182	-0.04113
	(-0.69)	(-2.22)
$\hat{\delta}_{\tau T}$	0.00470	0.00505
	(10.10)	(9.00)
$\hat{\delta}_{\varepsilon T}$	0.00063	0.00099
	(1.30)	(1.97)
$\hat{\phi}_{KT}$	0.00168	0.00052
	(2.79)	(0.85)
$\hat{\beta}_T$	0.01237	0.01219
	(30.25)	(29.07)
$\hat{\phi}_{TT}$	0.00022	0.00022
	(6.61)	(6.65)
R_Z^2	0.99895	0.99894
R_A^2	0.95832	0.96243
R_B^2	0.53118	0.54667
R_L^2	0.58015	0.58700
R_T^2	0.13936	0.13835

Table 2
Cumulated effects of changes in
the terms of trade, the real exchange rate, capital intensity, and technology on
openness, the trade balance and the labour share
1970–2005

	Openness (s_A)	*Trade balance* (s_B)	*Labour share* (s_L)
Terms of trade (τ)	-0.034	-0.043	-0.041
Real exchange rate (ε)	-0.020	-0.013	-0.007
Capital/labour ratio (k)	-0.051	-0.019	0.038
TFP (t)	0.177	0.035	-0.018
Residual	0.006	-0.021	-0.015
Total (1970–2005)	**0.078**	**-0.061**	**-0.043**