Openness to Trade as a Determinant of the Elasticity of Substitution between Capital and Labor

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Abstract

Some recent work on economic growth considers the aggregate elasticity of substitution between capital and labor as a measure of economic flexibility. It is thought to depend on technological and institutional determinants. I study how a openness to trade affects the aggregate elasticity of substitution of a large country in a Heckscher-Ohlin model with trade in intermediates and equalization of factor prices. With constant capital stocks, trade enlarges the set of available intermediates in the same way as a rise in the elasticity of substitution in their production would. An optimal tariff corresponds to an additional rise in the elasticity of substitution. In two growing economies, trade only rises the elasticity of substitution of the GDP function of the faster growing country.

Keywords: aggregate elasticity of substitution, normalization, Heckscher-Ohlin model, capital accumulation.

JEL classification: *F 11, E 23.*

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1 Introduction

Most people who are convinced that free markets work agree that international trade tends to make a country as a whole richer. They also agree that it tends to make some groups within a country worse off. In his book *Has Globalization Gone Too Far?* Rodrik (1997) draws attention to a parameter that could capture the negative effects greater openness to trade can have for workers: he argues that greater openness raises the elasticity of labor demand. If labor demand becomes more elastic, wages or employment react more strongly to exogenous shocks.

In a model of a closed economy with competitive markets, two factors of production, and a neoclassical aggregate production function, the absolute value of the elasticity of labor demand is equal to the elasticity of substitution between capital and labor. In an open economy, output and the ease of substitution between capital and labor depend, in addition to technology, on trading opportunities.

Recent work on growth has broadened the perspective from technological determinants to geographical, cultural and institutional determinants. Models with several sectors and several types of agents are widely used. At the same time, many theoretical and empirical exercises still represent the determinants of growth through a single aggregate production function. This function then represents technology in a narrow sense, as well as the efficiency of markets and the institutional environment.

The elasticity of substitution between capital and labor plays a fundamental role in growth models. In the Solow model a higher elasticity of substitution increases the steady state and makes long-run growth more likely (Klump and Preissler 2000, Klump and de La Grandville 2000). While the Cobb-Douglas function continues to be popular, a growing number of theoretical and empirical studies on the aggregate economy uses the more general CES production function. Most studies assume that technological change increases only the factor-augmenting efficiency parameters, not the substitution parameter. But some recent work addresses endogenous technological change that increases the substitution parameter. (Miyagiwa and Papageorgiou 2005, Benabou forthcoming). I extend this line of research into a different direction, arguing that the aggregate elasticity of substitution may depend on institutions and policy, in particular on openness to trade.

My purpose is not to show that openness to trade raises the aggregate elasticity of substitution under all conditions. Concerning the elasticity of labor supply, Panagariya (1999) demonstrates that the positive relationship breaks down if a restrictive theoretical setting is only slightly extended. The same will be true about the relationship between openness to trade and the elasticity of substitution established here. What I want to highlight are theoretical reasons to consider openness to trade as something that is reflected in the elasticity of substitution rather than in any other parameter of the aggregate GDP function. A positive relationship, however, exists only under certain conditions.

2 Theory and Evidence on Trade and the Aggregate Elasticity of Substitution

A previous paper (Saam 2005) considered the effects of an exogenous increase in the elasticity of substitution in a Ramsey model with heterogenous factor endowments. It suggests that the increase can be understood as a policy that makes the economy more flexible. The more flexible economy experiences higher growth. If initial conditions are bad, the economy can at the same time experience higher inequality. One possible cause of higher flexibility is greater openness to trade.

Ventura (1997) gives support to the view that trade liberalization is a determinant of the aggregate elasticity of substitution. He shows that a small economy with a finite technical elasticity of substitution can under free trade behave as if its elasticity of substitution were infinite. To understand the impact of differences in trade regimes on the elasticity of substitution, it is desirable to obtain further results for cases in which the elasticity of substitution remains finite and in which trade is partially liberalized.

Hicks' insights in *The Theory of Wages* (1963[1932]) remain fundamental in understanding determinants of the elasticity of substitution between capital and labor. He distinguishes three main determinants: first, substitution between products requiring different factor intensities, second, substitution between known methods of production, and third, substitution by new methods of production. In an additional chapter, written in 1934 and added to the second edition of 1963, Hicks points to a particular aspect of substitution: " The extent to which the export industries can expand [...] depends partly upon the willingness of the consumer to substitute imports for domestic goods [...] but it also depends partly upon the elasticity of the real demand for exports on the part of foreigners " (Hicks 1963[1932] p.300). He remarks that if one takes into account a measure of commodity substitution , "[the] combined elasticity of substitution between the factors is [...] the arithmetical sum of the elasticity of commodity substitution and our old technical elasticity of substitution" (p.298). Hicks' comments suggest that the elasticity of substitution depends on terms of trade as well as on a finite elasticity of substitution between home produced and foreign goods in production and consumption. I concentrate here on the first aspect.

On the empirical side, Slaughter (2001) estimates the effect of trade on own-price elasticities for production and nonproduction labor in U.S. manufacturing. He finds that labor demand in production has grown more elastic over 1961 to 1991 and that a number of trade measures have the predicted effect. But the effect vanishes for several trade measures once time is included as a variable.

Estimations of the aggregate elasticity of substitution have not formally studied its relation to trade. Duffy and Papageorgiou (2000) argue that richer countries tend to have a higher elasticity of substitution between capital and labor. Trade can possibly play a role in this. Yuhn (1991) finds a partial elasticity of substitution between capital and labor for Korea that is considerably higher than estimates for the United States. He sees one cause for the high elasticity in "price-distorting policies to artificially make the price of capital input cheap" that are aimed at promoting exports (p.344). In his view not trade liberalization alone but a state intervention would have increased the elasticity of substitution. As will be shown in section 4.4.3, this can be the case in a simple HOS model with a tariff.

3 Changes in Parameters of the CES Function

The parameters of the aggregate GDP function represent more than technological and entrepreneurial know-how. They also represent the efficiency of markets and institutions, unless these are explicitly represented in another element of the model.

In this section I give some general reasons why institutions can have an influence on the elasticity of substitution. In section 4.4 on the basic Heckscher-Ohlin model, I show in a more specific way how trade liberalization affects the elasticity of substitution. I restrict my considerations to the CES production function. They would not necessarily be valid for more flexible functional forms. These are, however, rarely used in theoretical research.

Using the normalization procedure by Klump and de La Grandville (2000), I define the following four parameters of a CES function: the baseline capital intensity k_0, the baseline profit share π_0, the baseline output per capita y_0, and the substitution parameter ψ, σ=1/(1 $-$ ψ) being the elasticity of substitution between capital and labor. The CES production function is written as

$$y = y_0 \left[\pi_0 \left(\frac{k}{k_0} \right)^{\psi} + (1 - \pi_0) \right]^{\frac{1}{\psi}} . \tag{1}$$

The literature on technological change considers changes in two parameters, in y_0 and in k_0. Changes in π_0 have not yet been considered. Here I represent technological change as a one-time shift in parameters, not as a continuous change. Hicks-neutral technological change corresponds to an increase in y_0 (Figure 1.1). Capital-augmenting technological change corresponds to a decrease in k_0 (Figure 1.3), labor-augmenting change to an increase in y_0 and a proportional increase in k_0 (Figure 1.2).

Hicks-neutral technological change raises output per person by the same rate for any level of capital per person. The effect of a one-time capital-augmenting improvement of technology vanishes with further capital accumulation. The effect of labor-augmenting technological change is always lower than the effect of neutral technological change at the same rate. But as k increases, the absolute effect of labor-augmenting technological change on output increases.

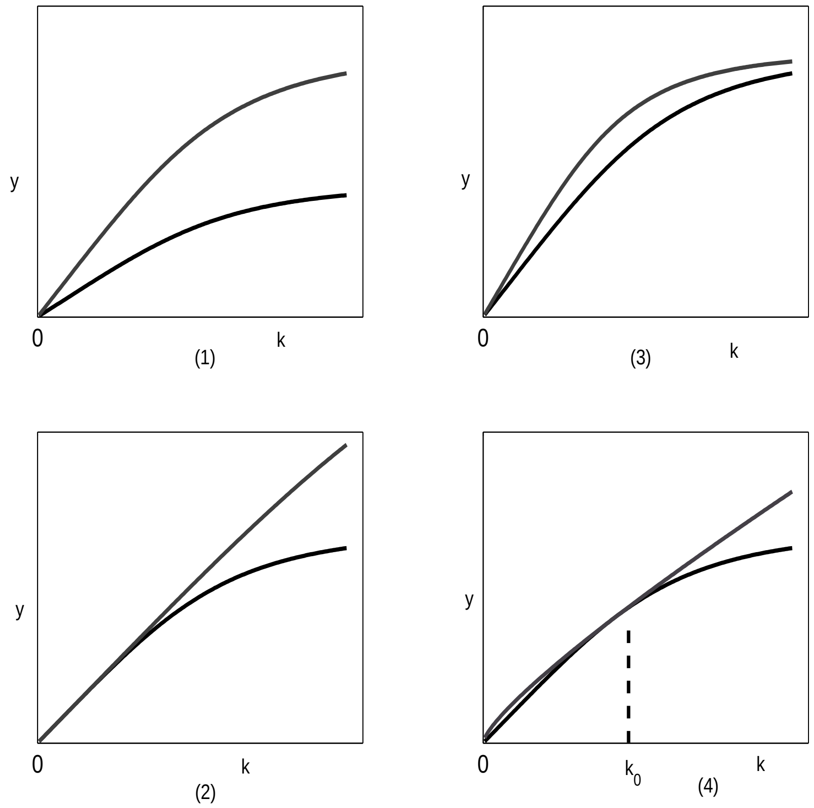

Figure 1: Increases in different technology parameters

Figure 1.4 shows an increase in the elasticity of substitution. Its effect depends on where the capital stock k lies relative to the baseline point. If one considers $k \geq k_0$ as the relevant situation (as Klump and de La Grandville suggest), the immediate effect is the higher the farther k is away from k_0. If σ rises to a level above one, the marginal product of capital increases permanently. By contrast, a one-time rise in factor-augmenting parameters cannot prevent the marginal product of capital from falling if the elasticity of substitution is lower than one.

In principle, changing technologies or institutions can alter any parameter of the production function. Depending on the kind of effect a particular parameter has on output, one can make conjectures whether the parameter depends more on technologies or more on institutions. Over the last decades we have observed rapid changes in technologies yet at the same time only moderate growth in some advanced countries. We do not know of any technological threshold above which long-run growth would be almost certain without further technological change. From this point of view it seems justified that most theories have modelled technological change as changes in y_0 or k_0 and not as an increase in σ. For σ there is a threshold above which endogenous growth always occurs. With continuous technological change acting on σ it would most likely move above the threshold. For factor-augmenting parameters such a threshold does not exist if the elasticity of substitution is low. Even for very high y_0 long-run growth without continuous technological change is not possible if $\sigma < 1$. Several recent estimations that include technological change find values of σ below one (Antras 2004, Klump et al. 2004).

For this reason I argue that the elasticity of substitution, although it can depend to some degree on technological change, mainly reflects an economy's institutions. Of course the same remark applies to institutions as to technology: we do not know of any institutional setting that would be sufficient to ensure long-run growth. So we should not expect institutional change to raise the elasticity of substitution above the threshold for long-run growth. But fundamental institutions, such as the existence of markets or property rights, have not changed as rapidly as technology. It does not seem implausible that an aggregate elasticity of substitution that depends on institutions remains below the threshold for long-run growth.

A further reason why technological change should have a more important effect on factor-augmenting parameters than on the elasticity of substitution is related to the fact that with a CES function, a rise in y_0 or a fall in k_0 always immediately increases output. A rise in the elasticity of substitution does not to have an immediate effect if the baseline point of the production function coincides with the actual point. Certainly there can be technological change without any immediate increase in productivity. With high costs of adaptation technological change can even decrease productivity. But many macroeconomic studies do not distinguish between creation and productive use of technology. On the other hand, major institutional changes can usually be identified more easily at the moment they happen than at the moment they increase productivity. Moreover, some will unfold their effects only in the course of factor reallocation or further capital accumulation. For example institutions fostering innovation will yield returns once new R&D is undertaken. In such a case it is plausible to assume that the economy is at its baseline point when the institutional setting improves.

In order to derive properties of the aggregate elasticity of substitution under trade formally, it is necessary to choose a simple model. Even in this simple model the elasticity of substitution is not constant.

4 The Heckscher-Ohlin Model with Trade in Intermediates

4.1 The Setup of the Model

The simplest framework in which the analogy between trade liberalization and a rise in the elasticity of substitution can be drawn is the 2x2 Heckscher-Ohlin-Samuelson (HOS) model. In the HOS model, I first consider a closed home country (H). The aggregate CES production function arises from two CES technologies for producing the intermediates X_1 and X_2 from capital and labor, and a CES technology for producing the final good from the intermediates. The production of X_1 is more capital-intensive than the production of X_2. I assume that all three CES production functions have the same elasticity of substitution. There are two reasons to introduce this simplification. First, it excludes factor-intensity reversals (see for example Bhagwati et al. 1998). Second, it ensures that, in a closed economy, the aggregate elasticity of substitution between capital and labor remains constant. The restriction is not stronger than the frequently made assumption of an aggregate CES function rather than a more general VES function.

Formally three equations represent the home country's technology:

$$X_{1H} = A[\alpha K_{1H}^{\psi} + (1-\alpha)L_{1H}^{\psi}]^{\frac{1}{\psi}}, \tag{2}$$

$$X_{2H} = B[\beta K_{2H}^{\psi} + (1-\beta)L_{2H}^{\psi}]^{\frac{1}{\psi}}, \tag{3}$$

$$Y_H = C[\gamma X_{1H}^{\psi} + (1-\gamma) X_{2H}^{\psi}]^{\frac{1}{\psi}}, . \tag{4}$$

with $K_H = K_{1H} + K_{2H}$ as the country's capital endowment and $L_H = L_{1H} + L_{2H}$ as the country's labor force.

Assuming payment of primary and intermediate factors of production at marginal product the relative price of intermediate goods is

$$p = \frac{p_2}{p_1} = \frac{1-\gamma}{\gamma} \left(\frac{X_{1H}}{X_{2H}}\right)^{(1-\psi)}. \tag{5}$$

As Miyagiwa and Papageorgiou (2005) show, the relation between changes in intermediate and factor prices is

$$\frac{\partial \ln (w/r)}{\partial t} = \frac{1}{\pi_1 - \pi_2} \frac{\partial \ln (p_2/p_1)}{\partial t}, \tag{6}$$

with π_i as capital share in sector i and t as time. As long as both sectors produce, this relation holds irrespective of the cause of changes in the relative price of intermediates.

Miyagiwa and Papageorgiou (2005) also show that, under autarky, the aggregate elasticity of substitution, defined as

$$\sigma = \frac{\partial \ln k}{\partial \ln w/r}, \tag{7}$$

is a weighted average of elasticities of the three production functions. In the special case considered here the aggregate elasticity of substitution remains constant in a closed economy.

It is assumed that a foreign country (F) has the same production technology but different factor endowments

$$X_{1F} = A[\alpha K_{1F}^{\psi} + (1-\alpha) L_{1F}^{\psi}]^{\frac{1}{\psi}} \tag{8}$$

$$X_{2F} = B[\beta K_{2F}^{\psi} + (1-\beta) L_{2F}^{\psi}]^{\frac{1}{\psi}} \tag{9}$$

$$Y_F = C[\gamma X_{1F}^{\psi} + (1-\gamma) X_{2F}^{\psi}]^{\frac{1}{\psi}}. \tag{10}$$

and that the two countries can trade. Z_1 are the home country's exportations of the intermediate X_1 and $-Z_2$ its importations of intermediate X_2, p is the relative price p_2/p_1. Trade is balanced:

$$Z_1 + pZ_2 = 0 \tag{11}$$

Under these assumptions final output in the home and in the foreign country corresponds to:

$$Y_H = C[\gamma(X_{1H} - Z_1)^{\psi} + (1-\gamma)(X_{2H} - Z_2)^{\psi}]^{\frac{1}{\psi}}. \tag{12}$$

and

$$Y_F = C[\gamma(X_{1F} + Z_1)^{\psi} + (1-\gamma)(X_{2F} + Z_2)^{\psi}]^{\frac{1}{\psi}}. \tag{13}$$

Maximization of final output under the constraints of the factor endowments, the technology, and balanced trade yields the following conditions:

$$p = \frac{p_2}{p_1} = \frac{\frac{\partial Y_H}{\partial X_{2H} - Z_2}}{\frac{\partial Y_H}{\partial X_{1H} - Z_1}} \tag{14}$$

and

$$p = \frac{p_2}{p_1} = \frac{\frac{\partial Y_F}{\partial X_{2F} + Z_2}}{\frac{\partial Y_F}{\partial X_{1F} + Z_1}}. \tag{15}$$

Plugging the derivatives of the production function and the trade balance (11) into (14) and (15) and solving for p yields the following expression for the terms of trade:

$$p = \frac{p_2}{p_1} = \frac{1-\gamma}{\gamma} \left(\frac{X_{1H} + X_{1F}}{X_{2H} + X_{2F}} \right)^{1-\psi}. \tag{16}$$

The elasticity of substitution is closely related to the evolution of the terms of trade. It is, however, not possible to solve analytically for the elasticity of substitution. In a static context I use a geometric argument to show why opening up to trade acts in the same way as an increase in the elasticity of substitution does. In a dynamic context in section 4.4 I return to the formal model. It is possible to infer the relative magnitude of the elasticities under autarky and under trade from the terms of trade.

4.2 Static Analysis of the Aggregate Elasticity of Substitution of a Large Trading Country

If the country opens up to trade, its final output depends on the amount of intermediates produced and traded and on the price of intermediates. The GDP function that determines final output depends on technology as well as trading opportunities.

For a small country, opening up to trade without complete specialization makes the factor prices independent of factor endowments. This amounts to a rise to infinity in the elasticity of substitution of the GDP function. For two large economies with the same technology but different factor endowments, trade offsets diminishing returns only to some extent. This amounts to a rise in the elasticity of substitution to a higher but finite level.

Now consider a large country trading with another large country, as specified in the previous section. Using the Edgeworth and Baldwin techniques, I show in a graphical representation that opening up to trade has the same effect on the availability of intermediates as a rise in the aggregate elasticity of substitution.

Baldwin (1948) shows that for a large country trading with another large country, the foreign country's offer curve can be combined with the home country's transformation curve in a way that yields the home country's availability locus under trade in the X_1-X_2-plane. The locus gives the combinations of intermediate inputs available under the home country's transformation curve, the foreign country's offer curve, and the price mechanism. For two large countries with the assumed production technologies with an equal elasticity of substitution, both the transformation curve and the availability locus are declining, and strictly concave unless the elasticity is infinite. The availability locus has one point of tangency with the transformation curve, representing the case in which the economies would choose not to trade (Figure 2). For two countries with given factor endowments the relevant part of the availability locus lies only in one direction of the tangency point. If it lay in the other direction it would mean a specialization of both countries in the production for which they have a comparative disadvantage.

I obtain a normalized transformation curve from normalized isoquants and show

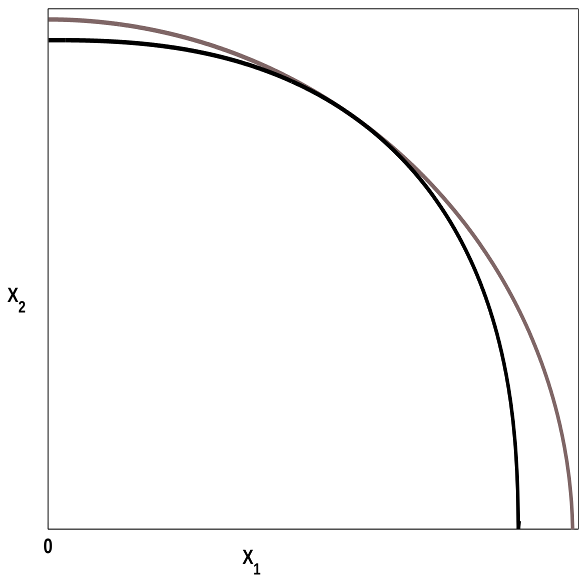

Figure 2: Transformation curve and availability locus of a large trading country

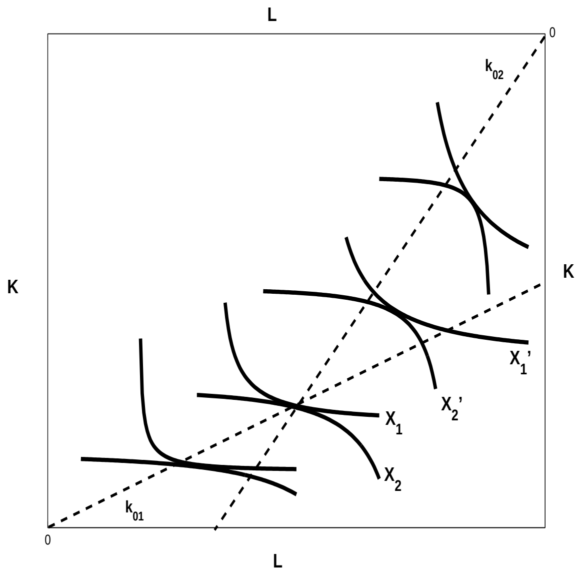

Figure 3: Isoquants determining the transformation curve

that opening up to trade has an effect analogous to a rise in the elasticity of substitution: while the transformation curve remains declining and concave, it is shifted outwards except in one point.

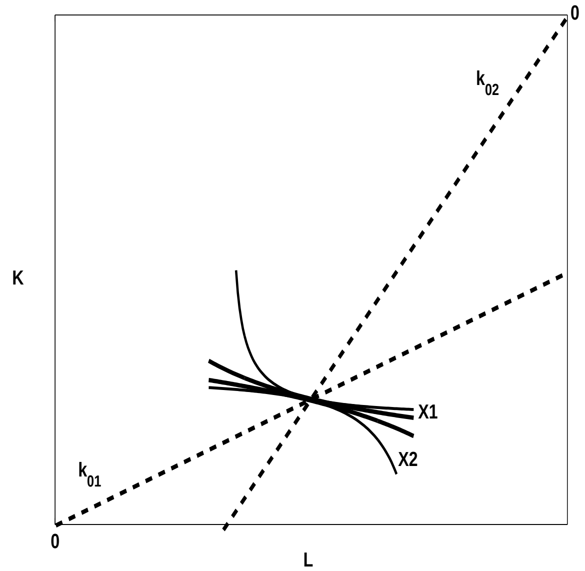

Figure 4: Increase in σ: change of isoquants in the point of normalization

The isoquants for each of the two sectors $i = 1, 2$ are normalized for a baseline ratio of capital to labor $k_{0i} = K_{0i}/N_{0i}$ at which isoquants with different elasticities of substitution have a common slope. In the Edgeworth-Box of the two-sector model, I define the baseline values k_{01} and k_{02} for the two production functions in a way that ensures one pair of isoquants to be tangent at their common baseline point. As factor intensity reversal has been excluded, there is no second pair of tangent isoquants on the lines representing the baseline capital intensities. From the continuity of the production function and the absence of factor intensity reversal follows that any other point of tangency lies between the rays k_{01} and k_{02} (Figure 3). Plotting the levels X_1 and X_2 corresponding to the isoquants one would obtain the transformation curve.

Now assume that the elasticity of substitution, which is at σ in both sectors, rises to σ'. The isoquants become flatter. For the output level of intermediate X_1 at the common baseline point of both technologies, the corresponding maximal output level of X_2 remains the same, the isoquants remain tangent (see Figure 4).

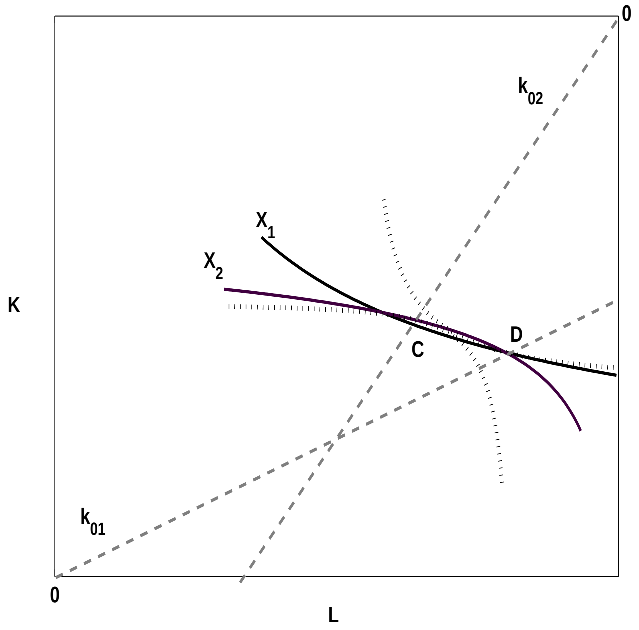

Figure 5: Increase in σ: change of isoquants outside the point of normalization

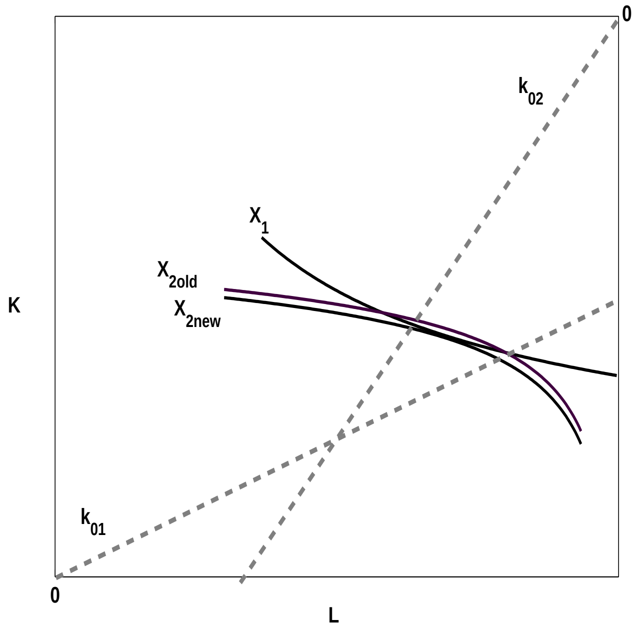

Figure 6: Increase in σ: given X_1, X_2 increases

Pairs of tangent isoquants corresponding to other available combinations of the intermediates (X_1,X_2), as the dashed isoquants in Figure 5, become intersecting after the rise in the elasticity of substitution. C and D represent their points of normalization. With a higher elasticity of substitution the isoquants flatten to the solid lines. For any given amount of X_1 outside the baseline point, the isoquant corresponding to the old maximal output of X_2 lies north-east of the isoquant corresponding to the new maximal output of X_2 (Figure 5).

In this case, an increase in the elasticity of substitution in the production of intermediates changes the set of available combinations (X_1, X_2) in the same way as opening up to trade does. I assumed the initial elasticities of substitution in the production of intermediates to be equal to the elasticity of substitution in the production of the final good. Thus, the aggregate elasticity of substitution as a weighted average of the three sectoral elasticities rises above its initial value as well.

4.3 An Ad Valorem Tariff in a Large Country

Now I show the effect of a tariff, again using Baldwin's geometric concepts: the availability locus already used in the previous section, and the Baldwin envelope. The Baldwin envelope represents the maximal amount of X_2 available given X_1, and given the transformation curve and the foreign country's offer curve. It does not take into account under what price mechanism the locus can be reached.

The Baldwin availability locus is obtained from superimposing the foreign country's concave offer curve on every point of the home country's transformation curve. In order to show the effect of a tariff, I show first that without a tariff, there are portions of the foreign country's offer curve (considered with any point on the transformation curve as origin) that lie outside the availability locus. Given a point P on the transformation curve, the corresponding point A on the availability locus is obtained from the intersection of the offer curve originating in P with the price tangent going through P (Figure 7). If the offer curve originating in P moves marginally to the left on the transformation curve, the offer curve is shifted by the price vector. For point A and any points to the left of it, this means a movement above the former offer curve, because the price vector is steeper than the offer curve. In addition to the shift in the offer curve, the price line flattens when P moves to the left. It follows that in A, the availability locus intersects the offer curve originating in P from above. This implies that moving on the offer curve from A to the right leads to points outside the availability locus. The argument applies for any X_1 lower than its autarky value. (Assuming that the comparative advantage of the country lies in the production of X_1 I disregard the other values).

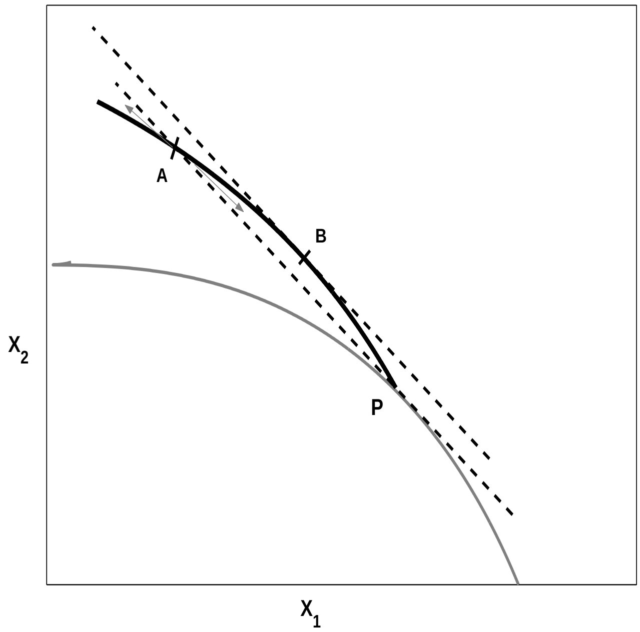

Figure 7: Small tariff moves point on availability locus from A in the direction of B

Starting from A, a small tariff on imports of X_2 turns the price-line up and moves the point of available intermediates south-east along the offer curve. Price line and offer curve intersect in a point that was previously outside the availability locus. This is true for any point on the availability locus. For any X_1, the amount X_2 that can be obtained by trade rises, except in the baseline point. Because of the concavity of the transformation curve and the offer curve, the new availability locus is concave as well. The small tariff has thus the same effect on the availability locus as an increase in the elasticity of substitution would have on the transformation curve of a closed economy. Raising the tariff further, this effect continues until point B is reached. At

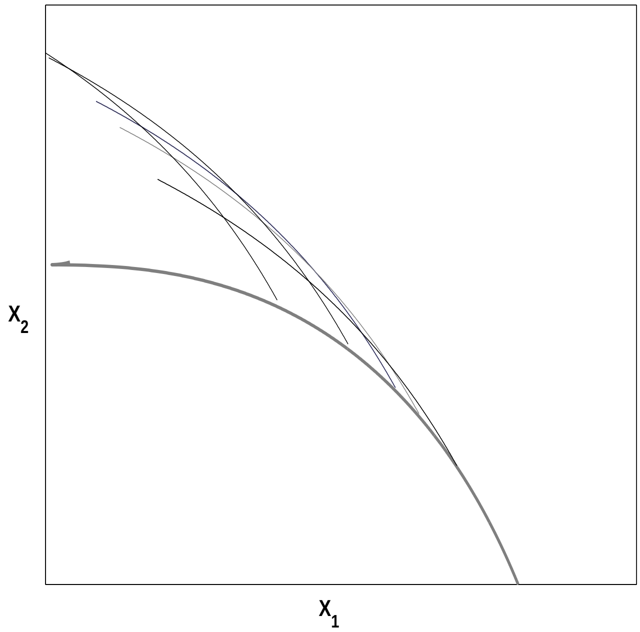

Figure 8: The Baldwin envelope

this point the availability locus under the tariff corresponds to the Baldwin envelope of the offer curves. Figure 8 illustrates the Baldwin envelope. If the tariff rate continues to increase, the point of intersection with the price line continues to move down the offer curve, this time moving back inside the envelope. The change of the availability locus is then analogous to a decline in the elasticity of substitution.

The result obtained here is a variant of the well-known result on the optimal positive tariff for a large country. Instead of maximizing welfare the tariff considered here maximizes output.

4.4 Dynamics of the Aggregate Elasticity of Substitution in Two Large Trading Countries

So far I have considered the transformation curve that can be derived given the country's capital stock and labor force. The elasticity of substitution is defined as the change in the capital intensity in relation to the change in the ratio of marginal products. But how is it possible to say that opening up to trade has the same effect as an increase in the elasticity of substitution without actually changing the capital intensity? This is because in the two sectors producing intermediates, the capital intensities can change, while the overall capital intensity remains constant.

The static effect of trade shown in section 4.2 corresponds to an increase in output following a rise in the elasticity of substitution at constant inputs. But the importance of the elasticity of substitution for the level of the steady state or even long-run growth does not reside in its one-time effect. Rather, it stems from the fact that a higher elasticity of substitution leads to a higher marginal product at any finite level of the capital stock.

One can move from a static to a dynamic context by simply considering the effects of trade for a sequence of capital stocks. As long as factor prices equalize in the two countries, output is always higher under trade than under autarky, because the set of available combinations of the intermediate goods expands. One can then measure the elasticity of substitution from the dynamics of the capital stock and the factor prices. Will the positive effect of trade on output translate into an elasticity of substitution that is higher than under autarky? This is not necessarily the case.

Suppose that trade with factor price equalization takes place and can be maintained during growth. Then the change in the factor price ratio is the same for both countries. What differs is the level and the growth rate of factor endowments. I am focusing here on differences in capital deepening, not on differences in population size. I therefore restrict the population in the home (H) and the foreign (F) country to $L_H = L_F = 1$.

I rewrite the equation for the terms of trade under factor price equalization (16) as

$$\begin{aligned} \frac{p_2}{p_1} &= \frac{1-\gamma}{\gamma}\left(\frac{X_{1H}+X_{1F}}{X_{2H}+X_{2F}}\right)^{1-\psi} \\ \Leftrightarrow p &= \frac{1-\gamma}{\gamma}\left(\frac{L_{1H}f_1(k_1)+L_{1F}f_1(k_1)}{L_{2H}f_2(k_2)+L_{2F}f_2(k_2)}\right)^{1-\psi} = \frac{1-\gamma}{\gamma}\left(\frac{L_{1total}f_1(k_1)}{L_{2total}f_2(k_2)}\right)^{1-\psi}, \end{aligned} \tag{17}$$

f_1 and f_2 denoting output per worker in production of the intermediates.

The relative price of the intermediate goods behaves as if the economy were completely integrated. I obtain the effect on the home country's elasticity of substitution from the following decomposition

$$\frac{1}{\sigma} = \frac{\partial \ln w/r}{\partial \ln p} \frac{\partial \ln p}{\partial \ln k_{total}} \frac{\partial \ln k_{total}}{\partial \ln k_H}. \tag{18}$$

With labor equal to one in each country, I define $k_{total} = k_H + k_F$.

Because the income shares in intermediate production are equal in both countries, the first component of the elasticity of substitution is equal for both countries (see equation 6). From (17) follows that the first and the second component together equal the inverse of the elasticity of substitution under autarky. Only the last component is specific to the home country. If the home country's growth rate in capital is larger than the foreign country's, its elasticity of substitution is higher than under autarky. Rewriting the term as

$$\begin{aligned} \frac{\partial \ln k_{total}}{\partial \ln k_H} &= \frac{g_{ktotal}}{g_{kH}} = \frac{\frac{k_H}{k_{total}} g_{kH} + \frac{k_F}{k_{total}} g_{kF}}{g_{kH}} \\ &= 1 + \left(1 - \frac{k_H}{k}\right)\left(\frac{g_{kF}}{g_{kH}} - 1\right) \end{aligned} \tag{19}$$

makes the effect of the *level* of capital clear. The higher a country's capital stock the closer its elasticity of substitution to the autarky value.

To sum up: in a world with two large trading economies with equal population size under diversification, trade raises the elasticity of substitution of the economy with higher growth in capital and lowers the elasticity of substitution of the economy with lower growth in capital. The effect is the more pronounced the lower a country's capital stock.

How can this result be reconciled with the static result that the production possibilities of a trading economy expand in a way that is analogous to an increase in the elasticity of substitution? First, the baseline point shifts with capital accumulation. It corresponds to the point in which the economies would not trade. Second, a dynamic economy shifts through different static transformation frontiers that have a higher elasticity of substitution than under autarky. The function that results from linking these points, however, does not necessarily have a higher elasticity of substitution, although output is higher than under autarky.

Under complete specialization, trade has no influence on the elasticity of substitution, because the relation between capital accumulation and factor price depends only on the technology of the sector which produces. As I assume all technological elasticities of substitution to be equal, the elasticity under complete specialization equals the elasticity under autarky. There has been doubt whether trade within the diversification cone is a relevant situation in a dynamic economy (Deardorff 2001). In the Solow model, factor price equalization is possible but does not always occur in the long-run. In the Ramsey model with different rates of time preference, factor-price equalization is impossible in the long-run. But if the economy starts within the cone of diversification, the economy will produce both intermediates during a part of the transitional growth path.

5 Other Aspects of Openness to Trade

In the HOS setting with equalization of factor prices the terms-of-trade effect causes changes in the elasticity of substitution of the GDP function. Introducing a tariff into the model I discussed one possible setting in which a barrier alters the terms of trade. Anderson and van Wincoop (2004) underline that trade costs remain large today and that direct policy instruments such as tariffs and quotas are only responsible for a small part of them. The larger part depends on other policies and institutions such as infrastructure, law enforcement, informational institutions, and language. Such informal barriers will not have any effect on the elasticity of substitution if they reduce returns to capital accumulation by a constant factor. But if trade volume rises with capital accumulation, one can expect that informal barriers to trade change marginal returns to capital accumulation. One example would be the exploitation of increasingly difficult trading opportunities, entailing increasing cost of information and transportation. A model of joint ventures by Rauch and Trindade (2003) works along these lines. They show how an improvement of information on potential foreign partners expands the opportunities for profitable joint ventures and raises the elasticity of labor demand. A meaningful model of informal barriers as determinants of the elasticity of substitution, however, will often require to model more than two factors of production, rendering the concept of elasticity of factor substitution ambiguous.

6 Conclusion

A growing part of research on economic growth focuses on institutions and policy. At the same time simple aggregate production functions continue to be used in theoretical and empirical research. As long as institutions and policy are not represented elsewhere in the model, they influence the parameters of the production function. The insights from the static HOS model with trade in intermediates suggest that under diversification, openness to trade has a positive effect on the elasticity of substitution between capital and labor, unless the economy is in the baseline point. In the context of trade theory, the baseline point can be understood as the point in which the country would choose autarky. The distance from the baseline point is related to comparative advantage.

If one departs from the static setting without distortion, additional conditions have to be fulfilled for the effect of trade on the elasticity of substitution to be positive. The reduction of a tariff only increases the elasticity of substitution if the tariff is not below the level at which the country optimally exploits its monopoly power. With capital accumulation, the elasticity of substitution only increases if the country has a rate of accumulation above average. The result seems to be consistent with the Yuhn's (1991) evidence on a high elasticity of substitution in Korea during a period of high capital accumulation and increasing trade.

While the conclusions are not necessarily robust to generalizations with more inputs, it might turn out that in further cases, a combination of growth-enhancing measures is reflected in a high elasticity of substitution.

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