Simultaneous Estimation of Income and Price Elasticities of Export Demand, Scale Economies and Factor Productivity Growth for Brazil

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Simultaneous Estimation of Income and Price Elasticities of Export Demand, Scale Economies and Total Factor Productivity Growth for Brazil[1]

Simultaneous Estimation of Export Elasticities and Productivity

Abstract

This paper focuses on a model in which low (high) export demand elasticities and the fact that developing countries are importers of capital goods help explaining the slow (high) growth of these countries. The question arises whether export demand elasticities are low or high. For answering this question, export demand elasticities for the case of Brazil are estimated using a growth model. As a by-product of estimating the model, we obtain estimates for total-factor productivity growth and for scale economies. Based on the results from estimation we calculate steady-state growth rates, engine and handmaiden effects of growth as well as dynamic steady-state gains from trade. The model and the results are discussed in regard to several strands of literature.

Keywords: Development, international linkages, open economy growth models, time-series.

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1. **Introduction**

Income and price elasticities of export demand are important for several reasons. When real devaluations occur, the value of exports increases (decreases) if export demand is price-(in)elastic. Therefore, more (less) imports can be bought from abroad. If imports are investment goods, this increases (decreases) investment. In particular, if technical progress yields lower terms of trade, this transmits more or less strongly into growth rates of exports and investment; and if booming exports drive up the terms of trade, it depends on price elasticities how strongly this boom is curtailing itself by boosting the terms of trade. Income elasticities of export demand determine how strongly growth abroad is translated into growth in exports. Again, if investment goods are paid for by these exports, the income elasticities of export demand have an impact on growth and on dynamic gains from trade.

In this paper, we estimate income and price elasticities of export demand from a slightly modified version of a two-gap growth model with imported inputs, introduced by Bardhan and Lewis (1970). In doing so, we hope to contribute to several strands of literature. First, the literature on exports and growth has benefited much from the insight that imported inputs paid by exports are the major mechanism in the relation between exports and growth in the short run (see Khan and Knight, 1988) and in the long run (see Esfahani, 1991). Similarly, Levine and Renelt (1992), and Wacziarg (2001) found that the major channel for trade and growth is investment. In line with that idea, recent time-series literature found that the causality going from exports to output growth is stronger than that going vice versa (see Riezman et al., 1996; Islam, 1998; Asafu-Adjaye and Chakraborty, 1999; Krishna et al., 2003).[2] Riezman et al. (1996) pointed out that this 'may serve as a guide to theorists who are currently working to develop better theories of economic growth'. We would like to recall that such a theory already exists since long: in the widely ignored model by Bardhan and Lewis (1970), exports are a second driving force for growth besides technical change because investment goods are imported. We use that model but go one step further: we estimate a full-fledged growth model rather than extended production functions or ad hoc specifications in order to get estimates of the export elasticities, total factor productivity growth and scale economies.

Second, growth and dynamic gains from trade are closely related since the question is whether trade increases the growth rate of the economy (see Lewer and van den Berg, 2003, for a recent survey). The larger the income elasticity of export demand the larger the growth rate of the economy in the model used below. Our estimates allow calculating the steady-state part of the dynamic gains from trade conditional on assumptions about future employment growth.

Third, the literature on balance of payments constrained growth is closely linked to that of two-gap models. In these models, the standard approach is to solve the balance of payments for the relative growth rate of the country in question and the world and to assume that terms of trade are constant or have no impact (see Bertola et al., 2002, for a recent contribution). The terms of trade have been made endogenous by Fagerberg (1988), who assumes that they equal relative unit labour costs, which in turn are exogenous though. In Verspagen (1993, Chap.7) relative unit labour costs depend on a Verdoorn effect, thus the terms of trade are endogenous. However, in his model, demand has no direct effect on the terms of trade as in the Bardhan and Lewis model, on which we base our estimates. In short, the demand side is added to that literature and we estimate its parameters in order to determine the effects of both, technological change and demand, on the terms of trade.

Fourth, there is the literature concerning the effects of devaluations or concerning the explanation of terms of trade movements. Here, the income and price elasticities of export demand are estimated from export demand functions (Riedel and Athukorala, 1995; Mody and Yilmaz, 1997; Senhadji and Montenegro, 1998), from partial equilibrium models of export demand and supply (Muscatelli, 1995; Madsen, 1999; Catão and Falcetti, 1999) and from demand side parts of a general equilibrium model (see Reinhart, 1995). In contrast to those approaches relying on partial equilibrium models, we use a growth model for our estimates.

Fifth, the slightly modified Bardhan and Lewis model serves as a theoretical foundation of the thoughts of Prebisch and Singer (see Ziesemer, 1995). Our estimates are the empirical complement to that theory, containing both parts of the history of economic thought, namely the engine and the handmaiden part of growth. As a by-product of our procedure, we also get estimates of total-factor-productivity growth and of scale economies for Brazil, which is the country for which we carry out the estimation.

The paper is set up as follows. In section 2 we present the model and compare it to the neoclassical growth model. Section 3 describes the data. Estimates of the growth model using the general method of moments estimator (GMM) are presented in section 4. In section 5, we use the estimated results to calculate steady-state growth rates, engine and handmaiden effects, and dynamic steady-state gains from trade. Section 6 relates the results to the aforementioned branches of the literature.

2. The Model

The question dealt with in this section is whether imports of capital goods and low (high) export demand elasticities could account for slow (fast) growth in comparison with the Solow (1956) growth model. The model assumes flexible wages and exogenous employment. A Cobb-Douglas production function with exogenous technical progress is used:

$$Y = e^{bt} A K^{\beta} L^{\alpha} U, 0 < \alpha, \beta < 1, \alpha + \beta \geq (\leq) 1 \quad (1)$$

Y denotes output, K capital, L labour, b the rate of technological progress, 'A' is a time independent constant, U a stochastic term and α and β the elasticity of production of labour and capital. We allow for increasing, decreasing and constant returns to scale. Labour is assumed to grow at rate ε, which is determined exogenously:

$$L(t) = L(0) e^{\varepsilon t}, \hat{L} = \varepsilon \quad (2)$$

A "hat" over a variable indicates a growth rate. The fact that they are importers of capital goods seems to be a fundamental problem of developing countries. Importing less luxury consumption goods may be helpful but cannot be a solution by itself. Therefore, it is assumed that no luxury items are imported. Problems referring to the terms of trade or growth may occur despite the absence of imports other than capital goods. Fundamental obstacles for developing economies are rather the importation of capital goods as well as limited export demand. By assumption, capital goods invested in developing countries must be imported:

$$M = \dot{K} \qquad (3)$$

A "dot" over a variable denotes its derivative with respect to time, and M represents imports. Capital goods are the only imports – another simplification besides the absence of foreign debt – and have to be paid for by exports. This requirement stems from the trade-balance equilibrium. Investments are, therefore, limited by exports, denoted by X, which are expressed in terms of the imported capital goods:

$$\hat{K} = \frac{\dot{K}}{K} = p\frac{X}{K} - \delta, \hat{\hat{K}} = \hat{p} + \hat{X} - \hat{K} \qquad (4)$$

p represents the terms of trade, defined as the price of domestic goods in terms of imported capital goods. Investments need to be paid for by domestic savings measured in terms of imported capital goods. The savings rate s is assumed to be a constant proportion of output in this theoretical part and depreciation is δK:

$$\hat{K} = \frac{\dot{K}}{K} = sp\frac{Y}{K} - \delta, \quad \hat{\hat{K}} = \hat{p} + \hat{Y} - \hat{K} \qquad (5)$$

Investments are limited by exports. Exports in turn are assumed to depend on the trade partners' income, Z, and on the terms of trade. For the sake of simplicity, a log-linear export function with a constant B[3] and a stochastic term V is used:

$$X = BZ^{\rho} p^{\eta} V, \rho > 0, \eta < 0 \qquad (6)$$

ρ denotes the income elasticity and η represents the (negative) price elasticity of export demand. Together, these six equations explain the six variables *Y, L, M, p, K,* and *X*.

Inserting the functions for exports and output, (6) and (1), into the export and saving constraint for investment, (4) and (5), respectively, writing the depreciation rate on the left hand side and taking natural logs, denoted *ln*, yields:

$$\ln(\hat{K}+\delta) = \ln B + \rho \ln Z + (1+\eta)\ln p + \ln V - \ln K \qquad (4')$$

$$\ln(\hat{K}+\delta) = \ln p + bt + \ln A + (\beta - 1)\ln K + \alpha \ln L + \ln U \qquad (5')$$

Uncertainty is kept as inessential and simple as possible here because we are not interested in any uncertainty aspect per se but rather need this aspect only to relate it to econometric models. Basically, the assumption is that firms know *L* and *K* (from the previous period) with certainty and produce after *U* has become known. Households then decide to save a fraction *s* of their income *Y* and this determines gross investment. When the V-term in the export function is known, *p* can adjust to determine external equilibrium. All rigidities and the implied consequences for the future are assumed to be absent for the sake of simplicity. In particular, the irreversibility of capital is assumed to be irrelevant. In a more sophisticated investment theory this is only justified if the optimal capital stock never decreases by more than depreciation.

In our model, the output per worker in units of domestic goods is considered a rough indicator of welfare. The driving forces behind the expected value (denoted by *E*) of the latter are the rate of technical progress and the growth rate of the capital-labour ratio, which is denoted by *k (*with *E(lnU)=0*):

$$\hat{y} = b + \beta\hat{k} + (\alpha + \beta - 1)\hat{L} \qquad (7)$$

The last term corrects for scale economies. Since the rate of technical progress is given, the remaining question is whether a low income elasticity of export demand hinders rapid growth of the capital-labour ratio by restricting the importation of capital goods. The growth rates for the long-term equilibrium growth path are of crucial interest in this respect. Solving equations (4') and (5') for the natural log of the terms of trade and the left hand side variable yields:

$$\ln(\hat{K}+\delta)=\frac{-\ln B}{\eta}+\ln A\frac{(\eta+1)}{\eta}+\frac{\eta+1}{\eta}\ln s+\frac{b(\eta+1)}{\eta}t+\frac{\beta\eta+\beta-\eta}{\eta}\ln K$$
$$+\frac{\alpha(\eta+1)}{\eta}\ln L+\frac{-\rho}{\eta}\ln Z+\frac{\eta+1}{\eta}\ln U-\frac{1}{\eta}\ln V \qquad (8)$$

$$\ln p=\frac{\ln A-\ln B}{\eta}++\frac{1}{\eta}\ln s+\frac{b}{\eta}t+\frac{\beta}{\eta}\ln K+\frac{\alpha}{\eta}\ln L-\frac{\rho}{\eta}\ln Z+\frac{1}{\eta}(\ln U-\ln V) \qquad (9)$$

The expected value (setting *lnU = lnV = 0* henceforth) of equation (8) is a differential equation of *K* with negative slope. K has an impact on equation (9) but *lnp* has none on (8).

The next step is to take the derivative with respect to time of both equations, set both sides equal to zero and assume a constant savings ratio in the steady state. Then the steady-state growth rate can be written as follows:

$$\hat{k}=\frac{\rho\hat{Z}-\varepsilon-(1+\eta)[(\alpha+\beta-1)\varepsilon+b]}{-\eta(1-\beta)+\beta} \qquad (10)$$

Inserting this solution into the equation determining the change in the terms of trade and into equation (7) yields the following solutions for the terms of trade and income per capita, respectively:

$$\hat{p} = \frac{(1-\beta)(\rho\hat{Z}-\varepsilon)-(\alpha+\beta-1)\varepsilon-b}{-\eta(1-\beta)+\beta} \qquad (11)$$

$$\hat{y} = \frac{\beta(\rho\hat{Z}-\varepsilon)-\eta((\alpha+\beta-1)\varepsilon+b)}{-\eta(1-\beta)+\beta} \qquad (12)$$

The numerators of equations (10) to (12) consist of three terms, the first of which reflects the "engine of growth" part from the export demand function: the growth rate of world income multiplied by the income elasticity of export demand minus the population growth rate. The product of trade partners' income and income elasticity is the driving force on the demand side. Hence, this part represents the ideas of Prebisch. The last part, on the other hand, captures the handmaiden part (see Kravis 1970). This term supports the view that technical progress leads to an increase in exports via decreased prices if exports are price elastic. Consequently, the causality of this last effects runs from growth to exports, opposite to what the engine of growth supporters propose. Our model contains both parts. Note, however, that the handmaiden part drops out if a country has no technical progress. The third part is only relevant in case of non-constant returns to scale. With increasing returns to scale we have an additional cost reduction which drops out only if *($\alpha+\beta=1$)* in (10)-(12).

The direct effect of technical progress and returns to scale is to decrease production costs and to reduce the terms of trade as can be read off equation (11). The question then arises whether this will cause exports and investments to rise or fall. Assuming exports are price-elastic, there will be an increase in exports and investments as well as in the capital-labour ratio in equation (10). If exports are price-inelastic, however, technical progress has a negative impact on the growth rate of the capital-labour ratio. Considering the growth rate of income per capita, it is obvious that technical progress has not only a direct but also an indirect effect on this variable. The latter effect is due to changes in the capital-labour ratio induced by technical progress. The direct effect outweighs the indirect one so that technical progress always has a positive impact on real wages.

Summing up, technical progress and returns to scale have a negative impact on the terms of trade while they influence per capita income positively. The higher the income elasticity the higher the growth of export demand for any growth rate of world income and the higher the growth rate of capital imports in equation (10). The latter aspect causes income in equation (12) to grow at a higher rate and the growth rate of the terms of trade is driven up as well. A higher growth rate of income in the trade partners' countries will lead to an increase in exports. Yet, the critical point is whether the change in income multiplied by the income elasticity, $\rho\hat{Z}$, exceeds the population growth rate ε. This difference governs the growth rate of the capital-labour ratio in equation (10) in case of constant returns to scale. If the income elasticity of export demand is low and the population growth rate is high, the effect on the growth rates concerning the terms of trade, the capital-labour ratio, and income per capita will be negative.

In conclusion, the terms of trade will fall on condition that the rate of technical progress and scale economies is not exceeded by a large difference between the export growth rate and the population growth rate in equation (12). The growth rates of the capital-labour ratio and income per capita may be negative because of low income and price elasticities. With respect to income elasticity and trade partners' income growth, the terms of trade are an indicator of economic development because they boost both, per capita income and the terms of trade.

Comparison with the Results of the Solow Growth Model

The Prebisch-Singer thesis poses the task of presenting trade conditions which result in a slower growth rate for the main economic indicators of welfare than in the Solow model. Considering a Solow model with a constant-returns-to-scale production function like equation (1), the capital-labour ratio and per capita income grow at the same rate, $b/(1-\beta)$. In the model examined above, this result can be obtained by means of taking into account two special cases. First, equation (12) can be written in the form:

$$\hat{y}=\frac{b}{(1-\beta)}\{1-\frac{\beta}{[\eta(1-\beta)]}\}+\frac{(\rho\hat{Z}-\varepsilon)\beta}{[-\eta(1-\beta)+\beta]}, \qquad (12')$$

For any value of $\rho\hat{Z}$, it holds that $\hat{y}=b/(1-\beta)$ assuming that η approaches minus infinity. This is the small country case in neoclassical models. Second, it can be shown that $\hat{y}=b/(1-\beta)$ and $\hat{p}=0$, both if $\rho\hat{Z}-\varepsilon=b/(1-\beta)$, just like a closed economy in the Solow model. Then, the engine of growth, $\rho\hat{Z}-\varepsilon$, has the same effect as the handmaiden part, $b/(1-\beta)$, and therefore, the growth rate coincides with that of the Solow model.

Figure 1 presents $\hat{y}$ as a function of ρ for different values of η under the assumption – made to emphasize the role of the income elasticity – that $\hat{Z} = \varepsilon + b/(1-\beta)$ and of constant returns for both models because the Solow model is normally presented in this way. The vertical intercept increases with the price elasticity of exports. The slope, on the other hand, is less steep the more price-elastic exports are.

FIGURE 1 OVER HERE

Due to equation (12'), there is one straight line for each value of η, being equal to $b/(1-\beta)$ at ρ=*1*. The horizontal line represents the small country case with the price elasticity being equal to minus infinity. It shows that in this case exports constitute no constraint to growth, a conclusion that is in line with traditional neoclassical thinking. Figure 1 reveals that the capital importing economy grows at a lower rate than in Solow's model if the income elasticity is lower than one. For income elasticities greater than one, the economy grows faster than predicted by the Solow model. These conclusions do not hold for a price elasticity of minus infinity, since this is the small country case.

In view of the interplay between the growth rate of the terms of trade and the income elasticity of export demand, a similar graph is drawn in figure 2. The less price-elastic exports the steeper the slope and the more negative the vertical intercept. For income elasticities smaller than one, the growth rate of the terms of trade fall and real wages grow at a lower rate than in the Solow model. There is, thus, a close relationship between the latter two variables. The driving force behind both of them is the income elasticity of export demand. The effect of the latter is reinforced by a lower price elasticity of export demand. The obvious corollary is that of a high price elasticity weakening the impact of the income elasticity of export demand on the developments of real income and the terms of trade. As in the previous graph, the relationship is drawn for $\hat{Z} = \varepsilon + b/(1-\beta)$ and alternative values for the price elasticity. To summarize, the price and income elasticities of export demand are crucial determinants for a developing country's growth prospects.

FIGURE 2 OVER HERE

In this model the importation of capital goods and low (high) elasticities of export demand contribute to explaining the slow (fast) growth of developing countries. The question now arises whether these price and income elasticities are indeed low. That issue is taken up in the following sections.

Again, we would like to point out the simplifying assumptions we have made: absence of domestic capital goods, imported consumption goods, foreign debt, and unbalanced trade. None of these assumptions holds true for Brazil as can easily be seen by examining the World Development Indicators.[4] Whether or not the abstraction is *too* strong will be revealed by the econometric work. After all, the widely used Solow growth model is a special case of our model. The former ignores imported inputs and the exports used to pay for them, whereas we ignore that a large part of capital goods is produced domestically. Furthermore, past empirical studies estimating export demand income and price elasticities use a similar export demand function but do not make use of a growth model for the supply side as we do. Integrating all of these neglected aspects in a fully-fledged model would require the estimation of many more parameters with a small number of observations. Therefore, it is not necessarily a drawback to use this simple model. In a model including domestic capital goods, these would have to grow at a rate that is proportional to that of foreign capital goods in order to avoid running too much into decreasing returns to the accumulation of one of them only. Absence of debt is dealt with by using the investment/GDP ratio rather than the savings ratio. Khan and Knight (1988), and Esfahani (1991) also assume all imports to be inputs. It can only be hoped for that the other aspects would merely change the intercept of the regressions below. This is a matter left for future work.

The equations estimated below are (8) and (9). Note that these equations hold for both, the steady state and the transition path. We want to estimate the equations as a simultaneous system. Once one equation is estimated, it is obvious that all parameters can be identified. Therefore, we have one constraint per regressor except for the intercept and the world income variable, which has the same coefficient in both equations.

3. The data

We decided to carry out the empirical estimation for Brazil because all data are available. In order to estimate the equations, time series for the savings or investment/GDP ratio, capital, trade partners' income and employment are required. The data for gross fixed capital formation as percentage of (GDP minus depreciation) are taken from the World Development Indicators 2004 and represent investment. We make use of this figure instead of the savings ratio in order to account for that part of investment financed by foreign debt, which is ignored by our model. The data for capital are constructed by cumulating Gross Fixed Capital Formation after subtraction of the data for depreciation, starting from an initial value determined according to the formula[5]

$$K_0 = \frac{I_1}{\left(\hat{K}_1 + \delta\right)}$$

Depreciation is assumed to be 3.7% of capital for all periods because this is the average value of available figures in earlier national accounts data. For I_1 we use gross fixed capital formation as of 1970. The initial growth rate of the capital stock in the above formula is assumed to be .1, which corresponds to the order of magnitude of the growth rates of GDP and employment in those years. With the capital stock obtained in this way we can determine growth rates as log differences and add the rate of depreciation to get the dependent variable of equation (8). The employment data are taken from the ILO website. The time series starts in 1972 but values for the years 1974, 1975, 1980, 1991, 1994, 2000, 2001 are missing. We do not try to interpolate them because in an earlier attempt we found that different ways of doing so removed the unit root processes in the time series. Trade partners' income is taken to be world income since Brazil is trading with all the countries in the world. The terms of trade are calculated as 'Exports as capacity to import' divided by 'exports of goods and services', both in terms of constant local currency units. Data are available in the appendix to the working paper version.

4. Econometric methods and estimation results for the system of equations

Econometric methods have been developed traditionally either for stationary variables and more recently for variables being integrated of order one, I(1). Before discussing the methods we check whether the time series follow unit root processes and determine the order of integration of the variables. Testing for unit roots suffers from the fact that these tests have been designed for a large number of observations whereas we deal with only a few observations. Hence, the tests have low explanatory power. For world income the ADF test does not reject the unit root hypothesis. All other variables do not follow unit root processes. Consequently, we use equations (8) and (9) with only one modification: we replace *lnZ* by *d(lnZ)*t*, which can be based on rewriting the export function as $X = e^{\rho d \ln Z * t} p^{\eta} = Z^{\rho} p^{\eta}$. The latter version of the variable does not have a unit root according to the standard ADF test. So we can use equations (8) and (9) in their current form.

The system has three important properties. First, there are constraints on the coefficients, generating a non-linear problem of estimation. Second, both equations of the system contain the random terms from the production function and the export function and therefore the residuals of the two equations will not be independent. These two properties together suggest using the seemingly unrelated regression (SUR) method. Third, equation (8) is a differential equation. Residuals have a positive impact on the dependent variable, enhancing the capital variable on the right hand side in the next period. As this is a stock variable, the effect is permanent. In other words, the residuals have an impact on all future variables of capital and the regressor in the first equation is not exogenous although it is predetermined (see Davidson and Mackinnon 2004, chapter 3.2). As this would bias the estimates, we use the generalized method of moments (GMM-HAC with heteroscedasticity and autocorrelation correction of the coefficient standard deviations) including all regressors and lagged variables of capital as instruments. We present the GMM estimate in the first column of Table 1 (see also unpublished Appendix to the working paper version).

TABLE 1 OVER HERE

The over-identifying constraints for the additional instruments are significant since the product of the J-statistic and the number of observations is low enough. As there are four constraints in the two equations, we have at least four degrees of freedom. However, the number of lagged instruments has to be added (see Greene 2003, p.548/9). The income elasticity of export demand (0.19) is at the lower end of the range of earlier estimates and the price elasticity (-1.86) is larger in absolute terms than in previous studies (see Table 2 for a comparison).

TABLE 2 OVER HERE

The time trend representing technical progress is significant and has the expected sign. The rate of total factor productivity growth is about 2%. Given the elasticity of production of labour of about .5, the labour augmenting rate of technical change is 4%. This figure is a bit larger than in estimations assuming constant returns to scale. However, the sum of the elasticities of production is .81 < 1 and indicates decreasing returns to scale at a measure of .19. If we arbitrarily (and therefore not shown) drop the time variable, we get increasing returns to scale. As shown above, the Solow growth model is a special case of our model in which the price elasticity should equal minus infinity. This would require c(2)=1. Given the high significance of the value around 0.5 it is clear that the alternative (to our model) hypothesis of the Solow model will be rejected by an F-test. The formulas for the identification of the parameters of the production function indicate that the estimated coefficients have to be in narrowly defined ranges in order to get reasonable parameter values for the model. In this sense the estimate for the system is quite encouraging. The only trouble here comes from the serial correlation as indicated by a very low DW statistic[6]. The standard procedure is to add lagged dependent variables. The result of adding one lag in each equation is shown in the second equation in Table1. The income elasticity of export demand is slightly higher now. The price elasticity has doubled. The growth rate of total factor productivity is now much smaller at about 1%. The decreasing returns measure is still .19 because the elasticity of production of capital is enhanced at the cost of that of labour. There still is autocorrelation in the first equation (also according to a Breusch-Godfrey test, which is not shown). In order to correct for this autocorrelation we save the residuals from the first equation and add their lagged values to the regression (also as instruments).[7] The result is the third regression in Table 1. The total factor productivity growth rate has fallen again to one third of a percent and has become insignificant again. We now get almost exactly constant returns to scale. The export elasticities are a bit lower than in the previous regression but still higher than in the first. Due to this last step of including lagged values of the residuals five observations are lost. Trying to carry out another Breusch-Godfrey test including one more lag leaves us with too little observations to do so.

5. Steady state growth rates, engine and handmaiden effect, and dynamic gains from trade

We have estimated the model for its non-steady-state version. For long-run predictions, the theory gives us the steady-state formulas for growth rates of expected values. Note that in the estimated parts of the model, no use was made of the assumption of perfect competition, which is not in accordance with increasing returns to scale. In this section, we calculate the steady-state growth rates for equations (10)-(12) numerically so as to specify the long-run predictions of the estimated models. We define and calculate the engine and handmaiden effect in order to compare them to each other and in order to compare them to the effect export growth rates have on GDP per capita growth rates in the survey of Lewer and van den Berg (2003). Finally, we calculate the corresponding growth rates of the Solow growth model as well as define the difference between the predicted growth of our model and that of the corresponding Solow model as the dynamic gains from trade.

TABLE 3 OVER HERE

In Table 3, we report the steady-state results for the growth rates of *k, p* and *y.* Additionally, the following effects – extracted from equations (10)-(12) – are presented: *g (m, s)* indicates the engine (handmaiden, scale) effect, obtained as the derivative of the formula for the growth rate of *y* with respect to the growth rate *dlnZ (b, dlnL)*.

$$g=\frac{\beta\rho}{\beta(\eta+1)-\eta},m=\frac{-\eta}{\beta(\eta+1)-\eta},s=\frac{-\eta(\alpha+\beta-1)}{\beta(\eta+1)-\eta}$$

The scale effect is the effect of *dlnL* only to the extent that it would drop out if there were constant returns to scale. Next, *x* represents the corresponding growth rate of the Solow model under the assumption that its parameters are identical to those of our estimates. Finally, the difference in the growth rates of our model, *dlny*, and the corresponding Solow model, denoted as *t*, is defined as the dynamic steady-state gains from trade. The parameter values are those from the last equation of Table 1.

$$x=\frac{b+(\alpha+\beta-1)\varepsilon}{\beta\eta+\beta-\eta},t=d\ln y-x$$

All calculations are done under the assumption that world income will continue to grow at *2.6%*. Finally, we need an assumption for the growth rate of employment. This rate was anything but constant in the past as can be seen from the following regression:

$$\ln L = 9.71 + .06t - .00057t^2$$
$$(212)\ (17.2)\ (-9.16) \qquad \text{adj.}R^2 = .993$$

A plot of the regression result and its time derivative representing the growth of employment appears in Figure 3. The result indicates that the growth rate of labour drops to zero at time $t>50$, which is after the year 2010.

FIGURE 3 OVER HERE

The results are as follows. The steady-state growth rates of capital and income per capita are positive only if employment growth is sufficiently small, at about *1%*. This is due to the low income elasticity of export demand and little technical progress. The presence of the scale effect is too weak to outweigh these two effects. The positive growth rates of the past are therefore generated by the transitional growth of capital accumulation. The terms of trade are falling – as the data reveals for the past – because the growth of the supply force, employment plus technical change, is larger than that of the demand force, world income multiplied by the income elasticity. The terms of trade are not falling, only in a steady state where population growth occurs at a rate of roughly .1%. The handmaiden effect, $m=1.27$, is larger than the engine effect, $g=.024$, and the scale effect, $s=-.0077$, again because the income elasticity of export demand and the measure of decreasing returns are very small. The handmaiden effect multiplied by the rate of technical change is still larger than the engine effect multiplied by the difference of world income growth rate and population growth rate. With lower population growth, this effect gets larger (see third but last line in Table 3) and the scale effect vanishes (last line of Table 3).

The closed economy growth rate is driven by decreasing returns to scale, employment growth and technical change. The lower future employment growth the higher will be the hypothetical autarkic growth rate. The growth rate of our model and the autarkic ones are higher if employment growth is lower. The steady-state part of the dynamic gains from trade becomes positive before employment growth is as low as .001 which will be the case around the year 2012 according to Figure 3, with period 1 representing the year 1960. Lewer and van den Berg (2003) illustrate that dynamic gains from trade are large when export growth rates are high in the transition after taking policy measures. Therefore, static gains from trade and the ones during transition may be larger than those in the steady state even if the latter are negative, which need not be the case if population growth falls far enough.

6. Conclusion

From the perspective of the exports and growth literature, we add economic causality – in the sense of estimating a growth model that contains an economic mechanism turning world income growth through exports via imported inputs into growth – to the econometric Granger causality of the literature. The model shows that the size of the income elasticity is crucial. According to our estimates, it is fairly low for Brazil and therefore the engine of growth effect is low as well.

From the perspective of the literature on balance of payments constrained growth, we have added the element of demand side effects on flexible terms of trade. It is obvious that price movements matter for the value of exports: If the income elasticity is larger than unity, growth will be enhanced through exports. If the income elasticity is lower than unity, growth will be reduced unless the price elasticity is minus infinity. A low income elasticity in connection with some technical progress leads to falling terms of trade in the steady state, giving rise to a relaxation of the balance of payments constraint. In the opposite cases, endogenous terms of trade lead to a tightening of the balance of payments constraint. This effect should be taken into account. Our empirical study shows that a low income elasticity dilutes the engine effect, the terms of trade will continue to fall in the steady state and therefore the balance of payments constraint is relaxed. Due to a relatively high price elasticity of about minus four growth is not hampered.

Next, there is the literature on devaluations, emphasizing the effects of devaluations or explaining the terms of trade movements. Keeping in mind that nominal devaluations have real effects (Bahmani-Oskooee and Miteza, 2002) our finding of a price elasticity of about minus four implies higher growth following devaluations.

Finally, from the perspective of the Prebisch-Singer thesis, the results clearly demonstrate that income and price elasticities of export demand may be important for the growth of Brazil in the period we have considered. In particular, if technical progress is low, a high world income growth multiplied by the income elasticity of export demand has to outweigh the population growth multiplied by the decreasing returns measure. Without the engine effect, i.e. in a closed economy, there would be no long-run per capita income growth if there are constant returns to scale and no technical change. Under increasing (decreasing) returns the impact of employment growth is less (more) negative than under constant returns. If population growth is low enough, the model allows for positive per capita income growth through imported capital goods, positive dynamic gains from trade and increasing terms of trade. However, if employment growth is large, negative rates are also possible. According to our estimates, the income elasticity is small, thus hampering growth and driving down the terms of trade in line with the Prebisch's expectations. However, the effect is only weak due to a relatively high price elasticity of export demand, which translates the falling terms of trade and therefore the effect of technical progress into a high export demand as expected by Kravis. Both arguments interact and are quantitatively relevant. According to our model, neither of the two can be dismissed because technical change matters on the supply side and exports are important determinants on the demand side.

The steady-state part of dynamic gains from international trade is dependent on the magnitude of employment growth: high employment growth yields negative dynamic gains from trade in the steady state whereas low employment growth brings about positive gains from trade. If employment continues to grow at such a high rate as in the past, dynamic gains from trade will be negative in the future. But the trend in employment data points to the opposite direction. As population growth approaches zero, positive dynamic gains from trade are generated by world income growth, which translates into higher demand for exports, and technical change multiplied by the price elasticity.

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Table 1: Regression results for the system of equations

	Method	**GMM (a)**	**GMM (d)**	**GMM (e)**
Variable	*Coefficient*	*Coeff/(t-val)*	*Coeff/(t-val)*	*Coeff/(t-val)*
constants		19.23/7.23	15.19/2.73	15.18/3.73
		10.51/3.16	8.76/3.21	5.24/3.2
lns	c(2)=(η+1)/η	0.46	0.80	0.7385
		(12.59)	(25.04)	(23.33)
t	c(3)=b*(η+1)/η	0.01	0.01	0.0025
		(2.89)	(2.24)	(.53)
lnK(-1)	c(4)=(βη+β−η)/η	-0.85	-0.72	-0.7888
		-(7.60)	-(7.04)	-(5.03)
lnL	c(5)=α(η+1)/η	0.23	0.36	0.5228
		(1.56)	(1.87)	(1.88)
dlnZ*t	c(6)=-ρ/η	0.10	0.07	0.0658
		(4.32)	(5.63)	(3.24)
lnkhatplusd(-1)		-	0.25	0.1339
			(7.16)	(2.57)
lnp(-1)		-	0.73	0.6886
			(13.46)	(13.09)
lagged residual				0.7174
				(3.08)
Identified parameters				
prod.elas.labour α		0.492	0.456	0.71
prod.elas.capital β		0.316	0.353	0.29
tot.faact.prod. gr.b		0.021	0.0096	0.00345
exp. inc.elas. ρ		0.193	0.328	0.25
exp.priceelas.η		-1.86	-4.94	-3.82
intial prod.level A		1.63x10exp(5)	2.6x10exp5	93504
exp.level param. B		1.14x10e11	1.83x10e11	1.48x10e11
adj.R-sq		0.88/.74	0.96/.87	.96/.87
No.obs		22/24	22/24	17/24
J statistic		0.32	0.459	0.449
nJ<c(d.f.) (b)		22x.32<18.31(10)	22x.46<18.31(10)	17x.45<19.68(11)
nJ<c(d.f.) (c)		24x.32 < 9.49(4)	24x.46<14.07(7)	24x.45<14.07(7)
Durbin-Watson		1.06/.88	1.52/2.25	2.04/2.24

(a) Instruments:regressors, plus lnk(-2) to(-7) in the first equation and none in the second.
(b) for the first equation at the 5%; degrees of freedom is number of constraints, which is 4, plus number of lagged instruments.
(c) for the second equation at the 5%;degrees of freedom is number of constraints, which is 4, plus number of lagged instruments.
(d) Instruments: regressors plus dlnk(-1) to (-5) and two lags of the dependent variable in the first equation and lnp(-2) to (-4) in the second.
(e) Instruments as in previous regression plus lagged residual regressor

Table 2: Overview of income and price elasticities of export demand for Brazil

Year	Author	Period	y	pm/pd	pm	pd
1969	Houthakker, Magee	1951-1966	0,34	-0,39		
1976	Lemgruber	1965-1974	1,97*	-0,41*		
1984	Aggarwal	1969-1978	0,253*	-1,23*		
1986	Bahmani-Oskooee	1974:1-1980:4	0,007	-0,151		
1988	Zini	1970:1-1986:3	0,690*		-0,171*	0,131
1992	Faini, Pritchett, Clavijo	1967-1983	0,60*	-1,51*		
1993	Bairam	1964-1985	3,93			
1995	Reinhart	1970-1991	2,447	-0,148		

y: foreign market income
pm: import unit value index
pd: domestic producer price or wholesale index
*: significance at 5% level
Source: Bairam (1988), Fullerton et al. 1999, Houthakker and Magee (1969), Reinhart (1995).

Table 3
Calculated steady-state growth rates, engine, handmaiden and scale effects and dynamic gains from trade for alternative values of labour growth

dlnL	0.02850	0.02000	0.01000	0.00500	0.00100
dlnk	-0.00420	-0.00134	0.00200	0.00374	0.00510
dlnp	-0.00630	-0.00430	-0.00194	-0.00077	0.00017
dlny	-0.00210	0.00295	0.00396	0.00448	0.00489
g	0.02387	0.02387	0.02387	0.02387	0.02387
m	1.27000	1.27000	1.27000	1.27000	1.27000
s	-0.00770	-0.00770	-0.00770	-0.00770	-0.00770
x	0.00460	0.00466	0.00475	0.00479	0.00480
t	-0.00250	-0.00172	-0.00077	-0.00031	0.00007
g*(dlnZ-dlnL)	-0.00006	0.00014	0.00038	0.00050	0.00060
m*b	0.00438	0.00438	0.00438	0.00438	0.00438
s*dlnL	-0.00022	-0.00015	-0.00008	-0.00004	-0.00001

Figure 1: The Relationship between the Growth Rate of per capita incomeand the Income Elasticity of Exports (for various Values of the Price Elasticity)

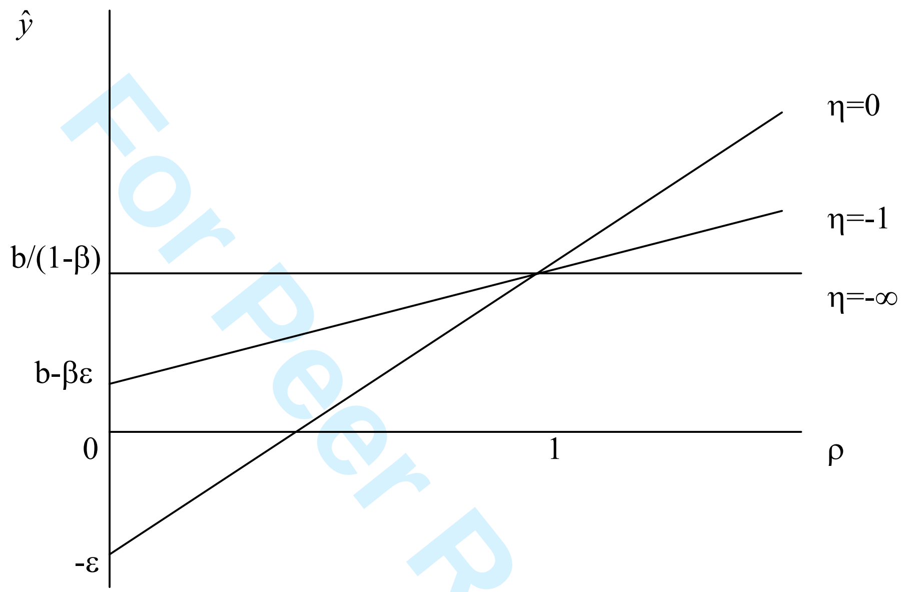


Figure 2: The Relationship between the Growth Rate of the Terms of Trade and the Income Elasticity of Export Demand (for various Values of the Price Elasticity)

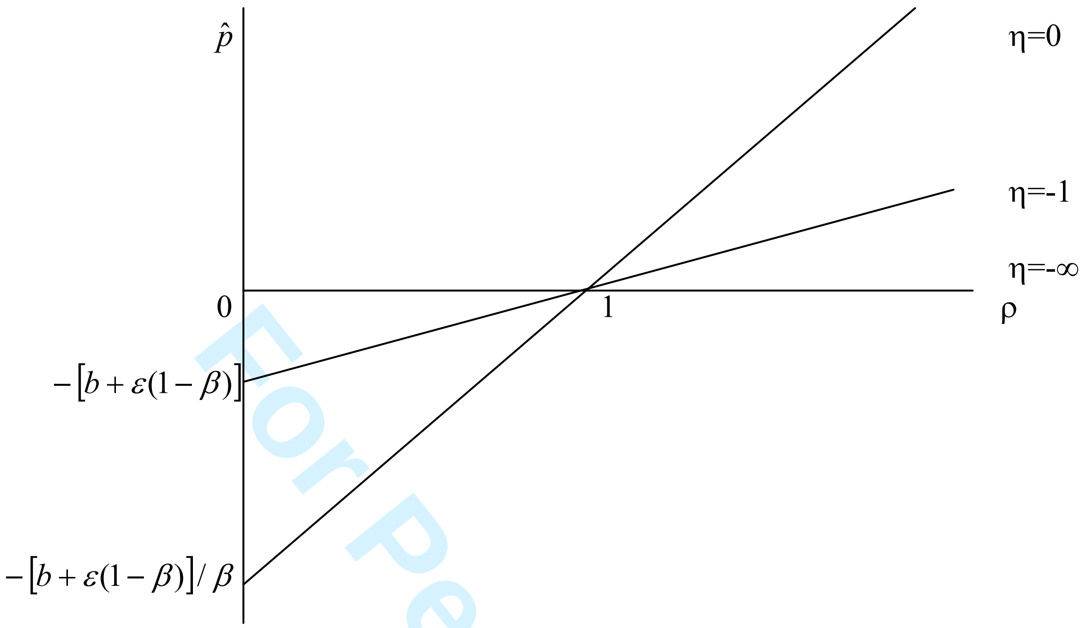
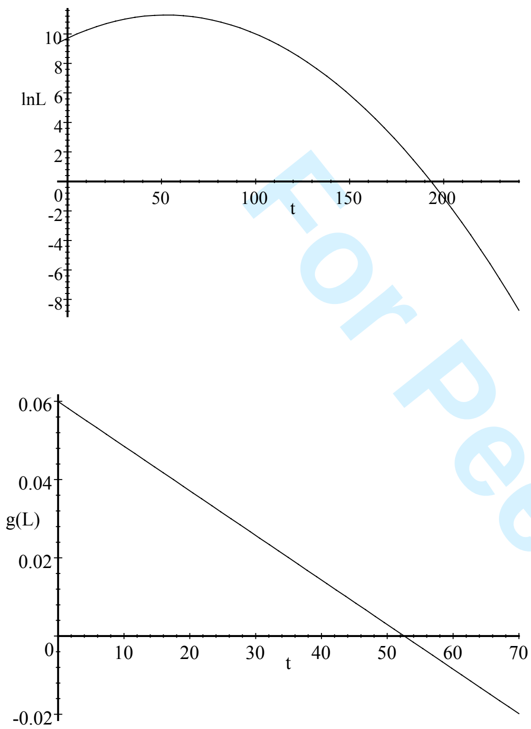


Figure 3: Plot of employment (in natural logs) and its growth rate



Appendix: Data (not for publication)

Brazil	lnkhatplusdeltalnK		t	lnL	lnZ	lnp	LNS
1960			1		29.69953	0.679	#VALUE!
1961			2		29.74695	0.592863	#VALUE!
1962			3		29.79947	0.3723	#VALUE!
1963			4		29.8486	0.386142	#VALUE!
1964			5		29.9136	0.523813	#VALUE!
1965			6		29.96258	0.547637	#VALUE!
1966			7		30.01905	0.511925	#VALUE!
1967			8		30.06499	0.486691	#VALUE!
1968			9		30.1248	0.451679	#VALUE!
1969		26.47896	10		30.18436	0.489117	#VALUE!
1970	-2.02261	26.57427	11		30.23037	0.575362	-1.617302
1971	-1.96591	26.6773	12		30.27136	0.560735	-1.569271
1972	-1.93139	26.78525	13	10.397543	30.32605	0.567483	-1.543731
1973	-1.8573	26.90434	14	10.473563	30.38831	0.678765	-1.488357
1974	-1.83147	27.02752	15	#NUM!	30.40205	0.495395	-1.426318
1975	-1.83757	27.14972	16	#NUM!	30.4104	0.466377	-1.356523
1976	-1.93903	27.25656	17	10.546341	30.45828	0.586685	-1.434932
1977	-2.04525	27.34891	18	10.6011	30.49625	0.716926	-1.482443
1978	-2.06595	27.43861	19	10.63499	30.53787	0.561119	-1.439907
1979	-2.05635	27.52953	20	10.662118	30.57846	0.461907	-1.403873
1980	-2.06323	27.61957	21	#NUM!	30.59732	0.29566	-1.40719
1981	-2.18973	27.69452	22	10.724698	30.61448	0.15327	-1.395637
1982	-2.32046	27.75575	23	10.777413	30.61862	0.143164	-1.457585
1983	-2.57474	27.79492	24	10.788618	30.6445	0.138787	-1.616392
1984	-2.63203	27.82985	25	10.82395	30.68893	0.20937	-1.688631
1985	-2.58808	27.86802	26	10.892304	30.7227	0.151116	-1.688791
1986	-2.43519	27.9186	27	10.922984	30.75537	0.296645	-1.573031
1987	-2.30033	27.98182	28	10.957974	30.79129	0.187074	-1.416217
1988	-2.34436	28.04073	29	10.980689	30.83669	0.277637	-1.392028
1989	-2.28746	28.10526	30	11.012413	30.87416	0.156823	-1.303492
1990	-2.56655	28.14506	31	11.036501	30.90294	-0.02475	-1.473271
1991	-2.72118	28.17385	32	#NUM!	30.91879	-0.06418	-1.602079
1992	-2.73742	28.20159	33	11.088201	30.93699	-0.12474	-1.58101
1993	-2.6732	28.23362	34	11.106009	30.95115	-0.0479	-1.53771
1994	-2.57727	28.2726	35	#NUM!	30.98128	-0.08493	-1.467335
1995	-2.58478	28.31102	36	11.150936	31.00905	0	-1.477455
1996	-2.66644	28.34352	37	11.126086	31.04075	-0.00191	-1.548237
1997	-2.64737	28.37735	38	11.146662	31.07486	0.011468	-1.528652
1998	-2.67397	28.40933	39	11.155722	31.09632	-0.03549	-1.519318
1999	-2.71031	28.43885	40	11.179911	31.12501	-0.12514	-1.529679
2000	-2.58009	28.47761	41	#NUM!	31.16374	-0.10866	-1.411217
2001	-2.66117	28.51048	42	11.231331	31.17652	-0.14293	-1.466674
2002	-2.73956	28.53808	43	#NUM!	31.19536	-0.13813	-1.526736

Appendix: GMM regressions (not for publication)

First regression in Table 1

System: SYS12
Estimation Method: Generalized Method of Moments
Date: 01/12/05 Time: 15:15
Sample: 1972 2001
Included observations: 24
Total system (unbalanced) observations 46
Estimation settings: tol=0.00010, derivs=analytic
Initial Values: C(1)=18.8587, C(2)=0.47086, C(3)=0.00970, C(4)=
-0.81866, C(5)=0.17414, C(6)=0.09331, C(7)=7.42517
Kernel: Bartlett, Bandwidth: Andrews (3.94), No prewhitening
Iterate coefficients after one-step weighting matrix
Convergence achieved after: 1 weight matrix, 10 total coef iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	19.22756	1.830304	10.50512	0.0000
C(2)	0.462891	0.036780	12.58534	0.0000
C(3)	0.009824	0.003400	2.889392	0.0063
C(4)	-0.853572	0.112293	-7.601293	0.0000
C(5)	0.227595	0.145824	1.560749	0.1267
C(6)	0.103396	0.023916	4.323295	0.0001
C(7)	7.228569	2.288196	3.159069	0.0031

Determinant residual covariance	4.73E-05
J-statistic	0.321189

Equation: LNKHATPLUSD = C(1)+ C(2)*LNS+C(3)*T+C(4)*LNK(-1)
+C(5)*LNL + C(6)*D(LNZ)*T
Instruments: C LNS T LNK(-1) LNL D(LNZ)*T LNK(-2) LNK(-3) LNK(-4)
LNK(-5) LNK(-6) LNK(-7)
Observations: 22

R-squared	0.910761	Mean dependent var	-2.440917
Adjusted R-squared	0.882874	S.D. dependent var	0.253595
S.E. of regression	0.086790	Sum squared resid	0.120519
Durbin-Watson stat	1.063375		

Equation: LNP = C(7)+(C(2)-1)*LNS+((C(2)-1)*C(3)/C(2))*T+((C(2)-1)
*C(5)/C(2))*LNL + (C(2)-1)*((C(4)+1)/C(2))*LNK(-1)+C(6)*D(LNZ)*T

Instruments: C LNS T LNK(-1) LNL D(LNZ)*T
Observations: 24

R-squared	0.795699	Mean dependent var	0.199807
Adjusted R-squared	0.738949	S.D. dependent var	0.265522
S.E. of regression	0.135664	Sum squared resid	0.331283
Durbin-Watson stat	0.882477		

Second regression in Table 1

System: SYS12
Estimation Method: Generalized Method of Moments
Date: 01/12/05 Time: 16:42
Sample: 1972 2001
Included observations: 24
Total system (unbalanced) observations 46
Estimation settings: tol=0.00010, derivs=analytic
Initial Values: C(1)=15.7413, C(2)=0.73475, C(3)=0.00753, C(4)= -0.54434, C(5)=-0.16702, C(6)=0.07191, C(8)=0.45229, C(7)=3.58979, C(9)=0.70147
Kernel: Bartlett, Bandwidth: Andrews (1.92), No prewhitening
Iterate coefficients after one-step weighting matrix
Convergence achieved after: 1 weight matrix, 15 total coef iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	15.19385	1.734346	8.760562	0.0000
C(2)	0.797500	0.031855	25.03566	0.0000
C(3)	0.007677	0.003429	2.239206	0.0312
C(4)	-0.718863	0.102134	-7.038409	0.0000
C(5)	0.362634	0.194307	1.866298	0.0699
C(6)	0.066517	0.011804	5.634965	0.0000
C(8)	0.253702	0.035419	7.162980	0.0000
C(7)	2.726818	0.849442	3.210129	0.0027
C(9)	0.727829	0.054080	13.45844	0.0000

Determinant residual covariance	1.03E-05
J-statistic	0.458764

Equation: LNKHATPLUSD = C(1)+ C(2)*LNS+C(3)*T+C(4)*LNK(-1) +C(5)*LNL + C(6)*D(LNZ)*T +C(8)*LNKHATPLUSD(-1)
Instruments: C LNS T LNK(-1) LNL D(LNZ)*T LNK(-2) LNK(-3) LNK(-4) LNK(-5) LNKHATPLUSD(-1) LNKHATPLUSD(-2)
Observations: 22

R-squared	0.972347	Mean dependent var	-2.440917
Adjusted R-squared	0.961286	S.D. dependent var	0.253595
S.E. of regression	0.049897	Sum squared resid	0.037346
Durbin-Watson stat	1.522321		

Equation: LNP = C(7)+(C(2)-1)*LNS+((C(2)-1)*C(3)/C(2))*T+((C(2)-1) *C(5)/C(2))*LNL + (C(2)-1)*((C(4)+1)/C(2))*LNK(-1)+C(6)*D(LNZ)*T +C(9)*LNP(-1)
Instruments: C LNS T LNK(-1) LNL D(LNZ)*T LNP(-1) LNP(-2) LNP(-3) LNP(-4)
Observations: 24

R-squared	0.905212	Mean dependent var	0.199807
Adjusted R-squared	0.871757	S.D. dependent var	0.265522
S.E. of regression	0.095086	Sum squared resid	0.153704
Durbin-Watson stat	2.250973		

Third regression in Table 1

System: SYS12
Estimation Method: Generalized Method of Moments
Date: 01/14/05 Time: 12:32
Sample: 1972 2001
Included observations: 24
Total system (unbalanced) observations 41
Estimation settings: tol=0.00010, derivs=analytic
Initial Values: C(1)=15.4047, C(2)=0.73729, C(3)=0.00299, C(4)= -0.79557, C(5)=0.51780, C(6)=0.06542, C(8)=0.13214, C(10)=0.75654, C(7)=3.67535, C(9)=0.68820
Kernel: Bartlett, Bandwidth: Andrews (0.53), No prewhitening
Iterate coefficients after one-step weighting matrix
Convergence achieved after: 1 weight matrix, 13 total coef iterations

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	15.17896	2.894769	5.243583	0.0000
C(2)	0.738511	0.031650	23.33386	0.0000
C(3)	0.002548	0.004835	0.526937	0.6020
C(4)	-0.788770	0.156757	-5.031788	0.0000
C(5)	0.522816	0.277918	1.881189	0.0694
C(6)	0.065827	0.020346	3.235290	0.0029
C(8)	0.133912	0.052101	2.570252	0.0152
C(10)	0.717384	0.232617	3.083970	0.0043
C(7)	3.733201	1.166555	3.200193	0.0032
C(9)	0.688591	0.052622	13.08568	0.0000
Determinant residual covariance			1.15E-05	
J-statistic			0.448536	

Equation: LNKHATPLUSD = C(1)+ C(2)*LNS+C(3)*T+C(4)*LNK(-1) +C(5)*LNL + C(6)*D(LNZ)*T +C(8)*LNKHATPLUSD(-1)+C(10) *RESID49(-1)
Instruments: C LNS T LNK(-1) LNL D(LNZ)*T LNK(-2) LNK(-3) LNK(-4) LNK(-5) LNKHATPLUSD(-1) LNKHATPLUSD(-2) RESID49(-1)
Observations: 17

R-squared	0.962889	Mean dependent var	-2.446356
Adjusted R-squared	0.934025	S.D. dependent var	0.234242
S.E. of regression	0.060166	Sum squared resid	0.032580
Durbin-Watson stat	2.036906		

Equation: LNP = C(7)+(C(2)-1)*LNS+((C(2)-1)*C(3)/C(2))*T+((C(2)-1) *C(5)/C(2))*LNL + (C(2)-1)*((C(4)+1)/C(2))*LNK(-1)+C(6)*D(LNZ)*T +C(9)*LNP(-1)
Instruments: C LNS T LNK(-1) LNL D(LNZ)*T LNP(-1) LNP(-2) LNP(-3) LNP(-4)
Observations: 24

R-squared	0.906524	Mean dependent var	0.199807
Adjusted R-squared	0.873533	S.D. dependent var	0.265522
S.E. of regression	0.094426	Sum squared resid	0.151575
Durbin-Watson stat	2.236543		

[1] We want to thank Harry Bloch and Bart Verspagen for useful comments on an earlier draft and Abraham Garcia, Clemens Kool, Pierre Mohnen, Franz Palm, Jean-Pierre Urbain for useful talks. Responsibility is entirely ours.

[2] Two recent publications are Dritsakis (2004) and Dawson and Hubbard (2004). They provide evidence for Central and Eastern European countries and many recent references to this bulk of literature.

[3] A separate estimate of the export demand function in terms of growth rates yields a growth rate of B which is insignificantly different from zero.

[4] For Brazil, Gross fixed Capital formation (GFCF) is about twice as large as total imports. For 1995 (but not for other years) we can calculate from the WDI that production of machinery and transport equipment is about $US 38.1 billion. This is about 25% of GFCF. However, of these $US38mln, 8.8 are exported, leaving about 29 for domestic investment. On the other hand, 21 are imported according to the UN Intern. Trade Statistics Yearbook, indicating that about 42% of machinery and transport equipment is imported provided it is not re-exported. Unfortunately it seems impossible to construct separate stocks of domestic and foreign capital without having similar information for other items and periods of GFCF than just machinery and transport as of 1995.

[5] See Verspagen (1995) for an extensive explanation.

[6] Below we will also employ the Breusch-Godfrey test because of the endogeneity problem discussed earlier, because the DW statistic is not the adequate tool in case of endogeneity.

[7] The idea comes from the standard Breusch-Godfrey test where the lagged residuals are added to the regression equation (see Davidson and MacKinnon 2004). We are aware of the fact that our procedure to use it as a correction for autocorrelation is only loosely related and that our approach may evoke a discussion. The only alternative we have is to focus on the other regressions with serial correlation.

Simultaneous Estimation of Income and Price Elasticities of Export Demand, Scale Economies and Total Factor Productivity Growth for Brazil

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Abstract

This paper focuses on a growth model in which (unlike other models) low (high) export demand elasticities and the fact that developing countries are importers of capital goods help explaining the slow (high) growth of these countries in the transition and in the steady state. The question arises whether export demand elasticities are low or high. For answering this question, export demand elasticities for the case of Brazil are obtained by estimation of the model. As a by-product of estimating the model, we obtain estimates for total-factor productivity growth and for scale economies. Based on the results from estimation we calculate steady-state growth rates, engine and handmaiden effects of growth as well as dynamic steady-state gains from trade. The model and the results are discussed in regard to several strands of literature.

Keywords: Development, international linkages, open-economy growth models, time-series.

JEL code: O11, O19, O41, F43, C51

Simultaneous Estimation of Income and Price Elasticities of Export Demand, Scale Economies and Total Factor Productivity Growth for Brazil

1. Introduction

Income and price elasticities of export demand are important for several reasons. When real devaluations occur, the value of exports increases (decreases) if export demand is price-(in)elastic. Therefore, more (less) imports can be bought from abroad. If imports are investment goods, this increases (decreases) investment. In particular, if technical progress yields lower terms of trade, this transmits more or less strongly into growth rates of exports and investment; and if booming exports drive up the terms of trade, it depends on price elasticities how strongly this boom is curtailing itself by boosting the terms of trade. Income elasticities of export demand determine how strongly growth abroad is translated into growth in exports. Again, if investment goods are paid for by these exports, the income elasticities of export demand have an impact on growth and on dynamic gains from trade.

In this paper, we estimate income and price elasticities of export demand from a slightly modified version of a two-gap growth model with imported inputs, introduced by Bardhan and Lewis (1970). In doing so, we hope to contribute to several strands of literature. First, the literature on exports and growth has benefited much from the insight that imported inputs paid by exports are the major mechanism in the relation between exports and growth in the short run (see Khan and Knight, 1988) and in the long run (see Esfahani, 1991). Similarly, Levine and Renelt (1992), and Wacziarg (2001) found that the major channel for trade and growth is investment. Edwards (1998) found a robust relation between openness and productivity, and pointed to open issues in regard to causality. In line with that idea, recent time-series literature found that the causality going from exports to output growth is stronger than that going vice versa (see Riezman et al., 1996; Islam, 1998; Asafu-Adjaye and Chakraborty, 1999; Krishna et al., 2003).[1] Riezman et al. (1996) pointed out that this 'may serve as a guide to theorists who are currently working to develop better theories of economic growth'. We would like to recall that such a theory already exists since long. In the widely ignored model by Bardhan and Lewis (1970), exports are a second driving force for growth besides technical change because investment goods are imported[2] and the terms of trade are endogenous. An extensive comparison with related models was provided by Ziesemer (1995). Models that either assume the importation of consumption goods rather than inputs or make a small country assumption will fail in giving the terms of trade a positive correlation with GDP per capita over time[3], and to give exports a crucial impact on growth even in the steady state. In the presence of technical change, the model can generate two-way causality between exports and growth. One-way causality whenever it is found in the empirical work (see Fosu 2001 for Africa) then indicates absence of technical change. A further advantage of the model is that it allows for permanent positive and negative growth even in case of absence of technical change rather than only for transitional growth as the neoclassical closed economy model does. Leung (2000) has pointed to the similarity of this type of models with that of endogenous growth models in case that the terms of trade

[1] Two recent publications are Dritsakis (2004) and Dawson and Hubbard (2004). They provide evidence for Central and Eastern European countries and many recent references to this huge literature.
[2] Some authors call this the 'Bhagwati assumption'.
[3] Eaton and Kortum (2001) show that prices of equipment relative to consumer prices - the inverse of our terms-of-trade measure - are negatively correlated across countries in 1985. These differences in prices explain 25% of productivity differences in their analysis. They attribute 50% of the cross country price differences to geographic and other barriers to trade, whereas our model emphasizes the growth of exports relative to total factor productivity growth, over time in explaining terms of trade growth. These export

are increasing. Endogenous growth models endogenize the rate of labour-augmenting technical change through research and development expenditures, multi-nationalization and imitation. In these models the rate of growth is proportional to that of the number of northern and southern goods, the latter produced by multinationals or imitating domestic firms (Lai 1998). The growth rates of these numbers are all the same in a steady state and are also equal to the difference in the rates of growth of labour demand and labour supply if there are complete international spillovers of R&D knowledge. The reason for this similarity with the Solow model is the unit income elasticity of demand for all goods, which makes sure that the South and the North grow at the same rate. Unlike our modified Bardhan/Lewis model, there is no possibility of catching up or falling behind in the steady-state of these models.[4] If spillovers are only national or limited to an industry or to some goods of an industry Northern and Southern growth rates may diverge (Grossman and Helpman 1995). However, because of the assumption of homothetic preferences, the income and price elasticities of export demand never appear in the formulas for long-run growth rates, as they do in our modified Bardhan/Lewis model.

Of course, the Bardhan/Lewis model is an exogenous growth model. But the increase (decrease) in the terms of trade when world income (per domestic worker) grows quickly (slowly) or the income elasticity of export demand is high (low) allows for positive (or

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constraints can be broadly interpreted as part of their 'capacity to absorb advanced technology from abroad' (p.1218).

[4] Closely related are models with trade in capital goods. Homothetic preferences and production functions are used in international real business cycle models with trade in capital goods. There is no effect of trade in capital goods on the long run growth rate, but rather only on the volatility (Boileau 1999), because of the implied unit income elasticity. Similarly, Honkapohja and Turunen-Red (1999) show that two symmetric R&D driven economies when trading capital goods may have multiple steady states. Trade liberalization may induce the vanishing of some of them. These may be the high-growth or low-growth steady states. Again, there is no role for income and price elasticities of export demand in long-run growth. Moreover, these models as those for international real business cycles are more suitable for developed countries, because they have no developing country features.

negative) permanent growth even without technical progress. With and without technical change, the long-run growth rates may be positive, zero, or even negative, which is important because all three cases can be seen in the data (see Temple 1999, Table 2). We use that model but go one step further. We estimate equations as derived from a full-fledged growth model. We hope that this is a step as interesting as the estimation of purely empirical models[5], each of which has his own problems (see Durlauf, Johnson and Temple forthcoming) as does ours. Through this approach we get estimates of the export elasticities, total factor productivity growth and scale economies in the same form as they appear in theoretical models. In particular, this is very much different from estimating growth regressions using variables of the Solow growth model and then adding trade and openness indicators. Rather the model integrates trade and growth right from the beginning, has a clear explanation of the link between trade and growth, and estimates income and price elasticities of export demand and other parameters of the model, all of which need to be within reasonable ranges. As the model has the above mentioned realistic properties we thus obtain a strong integration of the theoretical model and the econometric estimate rather than having them connected only loosely. In other words, it is a well-known statement in econometric textbooks that models also provide a straightjacket, and therefore estimates based on theoretical models are the more ambitious task we want to pursue.

Sachs and Warner (1995a) found that natural resource abundance is related to lower growth. One of the reasons for this may be the low income elasticities of export demand

[5] Examples of purely empirical models are extended production functions, or purely empirical specifications as in the traditional cross-country regressions (Fosu 2001), panel estimates (Savvides 1995),

for these goods, which translate into lower imported investments according to our variant of the Bardhan-Lewis model.[6] In this model, openness and capital accumulation are not competing explanations of growth (see Fosu 2001, p.287), because openness enhances the export volume, which is available for importing investment goods, as emphasized by Sachs and Warner (1997) and Rodrik (2000). Specialization on goods, natural resources or others, contribute positively (negatively) to growth if they have high (low) income elasticities of export demand. High export taxes may be an effort to deal with falling terms of trade in order to keep tax revenues high. This has been suggested to have negative effects on growth though (see Sachs and Warner 1995b, Collier and Gunning 1999 and Fosu 2001 on Africa, and Berg and Krueger for a broad survey). From the perspective of our model these may be negative effects on the transitional part of the growth rate as an extension to export taxes can have only level effects in the steady-state of our model. Thus, trade policy liberalization is expected to contribute to transitional growth if trade taxes are higher than the optimal ones (see Fosu 2001) according to our model.

Much of the evidence uses three indicators for openness: the Sachs-Warner (1995b, 1997) measure, black market premia for exchange rates (Easterly and Levine 2001), and the sum of exports and imports (trade volume) divided by the GDP (Savvides 1995, Easterly and Levine 2001, Dollar and Kraay 2004[7]) to show a positive relation between

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the above mentioned time-series literature and vector-autoregressive models and related advanced techniques (Awokuse 2005).

[6] Sachs and Warner (1995a) themselves favour a Dutch disease interpretation. The subsequent literature has emphasized many other aspects. For example, Kronenberg (2004) found a relation with corruption and a neglect of basic education for former communist countries. They can all be viewed as complementary to our explanation.

[7] Surprisingly, Dollar and Kraay do not include the standard variables investment/GDP, population growth and human capital in their regression of growth on trade volumes. Even if trade is correlated with

trade and growth.[8] Some doubts on the robustness of these cross-section regressions have been raised. Harrison and Hanson (1999) decompose the Sachs-Warner measure of openness and show that the trade policy components are not significant in their growth regressions. They conclude that the time-series dimension should be included.[9] Similarly, Rodríguez and Rodrik (2001) show that in many often cited papers it is not the trade policy component of openness indicators that drive the results, and misspecifications are discussed extensively leaving the authors with the conclusion that there is no conclusive evidence for a positive or negative correlation between trade liberalization and growth 'for levels of trade restrictions observed in practice'. One of the theoretical underpinnings for the possible absence of growth effects from trade liberalization comes from the possibility that import-competing sectors may *produce and receive* stronger dynamic learning effects than the other sectors. Trade liberalization lowers these effects resulting in a negative net effect of trade liberalization on growth (Rodríguez and Rodrik 2001). For the case that the import-competing sector produces stronger learning effects than other sectors, but the effects are received by all sectors equally this may be outweighed by positive effects from importing capital goods more cheaply in a balanced growth model with North and South growing at the same rates in the long run if the learning effects generated by the two sectors are not too different (Goh and Olivier 2002). In short, there is no way of excluding a zero or negative relation between trade and growth in economic theory and the evidence is so far inconclusive. Growth represents potential

investment, the inclusion of the latter two variables seems to be a 'must' to us. Similarly, Sachs and Warner (1997) do not include labour force growth or population growth but rather only the difference of the two.

[8] See the survey by Berg and Krueger (2003) for many other references and other approaches.

[9] Harrison and Hanson (1999) do not include population or labour force growth. Moreover, the authors include the relative price of investment goods, which turns out to be highly significant. This variable may be correlated with trade policy variables. Rodríguez and Rodrik (2001) argue that these prices are likely to be endogenous. This casts some doubts on the robustness of this approach to checking robustness.

future benefits of trade liberalization. But, as Rodrik (2000) points out, these should not be oversold because of doubts on the robustness, and the costs of adjustment, and because losers should not be overlooked but rather dealt with by accompanying reforms in a country-specific manner and, given scarce resources, other reforms may be more worthwhile. The critique of Rodríguez and Rodrik (2001) though is focussed on trade policy indicators, not the trade volume indicators recently used by Savvides 1995 and Dollar and Kraay (2004). The missing link therefore is to show that trade liberalization is causing higher trade volumes as one would expect from the partial reasoning of basic trade theory.[10] Moreover, the empirical literature has not tried to make a distinction between countries being on this or that side of the optimal tariff. Our model could be extended to include an optimal tariff but this is not the purpose of this paper and, given the weak evidence, not even necessarily improving realism. Instead we focus on income and price elasticities of export demand as determinants of the growth of exports, terms of trade and growth. So much about exports and growth, including trade policy; we hope to have indicated that our model can reconcile some seemingly controversial views in that literature once the emphasis shifts to imported capital goods and income elasticities of export demand.[11]

[10] Establishing this link is not as easy as it might be expected. Wilson, Mann and Otsuki (2003) find that the significance of the effect of tariffs on bilateral trade flows in a gravity model break down once due time lags and omitted variable biases are treated adequately.

[11] Other theoretical links between trade (liberalization) and growth are discussed by Fosu (2001) and Berg and Krueger (2003). They are understandable on the basis of the static theory of international trade and the comparative static growth effects: 1. Resources move to the exporting sectors, which have higher productivity than other sectors, and therefore give more weight to the higher productivity of the exporting sectors. 2. Economies of scale are realized in the exporting sector – with corresponding losses in the shrinking importing sectors. 3. Reductions in inefficiencies through more fierce competition. 4. Imported capital goods as emphasized by our model would also include new technologies and management knowledge. 5. Knowledge spillovers from R&D of trading partners enhance productivity. In how far these links work is a matter of emphasis of the respective authors. 6. The dynamic analogue to point 1 is that exporting sectors may have higher productivity growth rates than the other sectors. Giving more weight to them implies a higher growth rate. It should be pointed out though that all studies of factor productivity

Second, growth and dynamic gains from trade are closely related since the question is whether trade increases the growth rate of the economy (see Lewer and van den Berg, 2003, for a recent survey). The larger the income elasticity of export demand the larger the growth rate of the economy in the model used below. Our estimates allow calculating the steady-state part of the dynamic gains from trade conditional on assumptions about future employment growth.

Third, the slightly modified Bardhan and Lewis model serves as a theoretical foundation of the thoughts of Prebisch and Singer (see Ziesemer, 1995 for the theory and Ocampo and Parra 2003 for a recent contribution on the empirics). Our estimates are the empirical complement to that theory, containing both parts of the history of economic thought, namely the engine and the handmaiden part of growth, the first emphasizing exports' effect on growth (Prebisch 1950) and the second growth's effect on exports (Kravis 1970). In a modified form though, these opposing views appear nowadays among the openness proponents and the sceptics with the latter emphasizing technical change

growth find quite a few countries with no factor productivity growth. On the other hand, trade liberalizations when stretched out over a long time repeat the static effects making them look like dynamic ones unless the time structure of liberalization policies are explicitly incorporated in the regressors. 7. Demonstration and learning effects from foreign subsidiaries to domestic firm may induce learning. This aspect seems to remain controversial among empirical researchers. 8. Similarly, productivity effects from learning-by-doing or by exporting, which were well established in the literature, are challenged now by the econometrics of self-selection.

In addition we have (often similar) arguments from endogenous growth theory: 9. Compared to autarky, opening up enhances available ideas and intermediate inputs (Romer/Rivera-Batiz). Note that this can be valid only for closed countries or if transmission of ideas depends on trade contacts. Without the latter assumption it is unlikely that more ideas flow if there is a small tariff reduction. Flows of ideas and availability of intermediates depend on having some trade but not necessarily on trade volumes. 10. If countries specialize on high- and low-skill intensive goods respectively and growth is produced by an even more high-skill intensive non-traded third R&D sector, the country relatively abundant with high-skilled people will get lower growth and the other country higher growth because of the competition for high-skilled people, who move out of (into) the R&D sector in the country specialized in high-skilled (low-skilled) goods (Grossman/Helpman). 11. If import-competing goods have stronger learning effects related to production, growth may get higher through tariffs as long as the dynamic effect is stronger than the static distortion (Rodríguez and Rodrik 2001 referring to Matsuyama). This is the dynamic mirror image of the static argument in point 2. 12. Point 11 may be invalid if capital goods are imported by the country supposed to slow down (Goh/Olivier).

(see Fosu 2001, p.290).[12] However, a model with imported capital goods and endogenous term of trade reconciles the views on the conceptual level, and the empirical relevance may differ from country to country[13] and across historical phases. The reason is that countries may be specialized on goods with high or with low income elasticities. As Ocampo and Parra (2003) show, the terms of trade for commodities are captured by indices with two structural breaks in 1921 – a sudden drop with no trend before and after 1921 - and in 1979, with a negative trend afterwards. Both breaks occur when world demand is weak. The phase of falling terms of trade in the 1980s suggests a stronger growth of supply compared to demand, in our model captured respectively by technical change and world income growth multiplied by the income elasticity of export demand. The stationary phases suggest equal growth of supply and demand. The indices used consist of single commodities some of which have strong positive growth rates, others have negative ones, and those with no trends may have a strong accumulation of shocks. Depending on their specialization countries may be lucky or not. In our model this luck is captured by the income elasticity of export demand, which may be high or low depending on the commodities produced. The structural break of the 1920s had been found earlier by Powell (1991), who also found one for 1937 and 1975, all related to the cointegration of terms of trade for commodities and manufactures. Bleaney and Greenaway (1993) found a shock after 1980, but constant terms of trade from 1925-1980. UNCTAD (2005) reports strongly rising commodity terms of trade since 2002 and also falling prices of

[12] Emphasizing trade issues in no way should imply deemphasizing the relevance of public services, education and infrastructure. They are the domestic counterparts of trade, creating and destroying the comparative advantages.

[13] Readers more interested in country-specific analyses (as Easterly and Levine 2001) should not overlook the survey by Reynolds (1983), which reconciles the historical evidence with what is captured by growth and development models.

manufactures of developing countries relative to those of the developed countries. The rise in commodity terms of trade is likely to be another structural break caused by the growth of India and China. Given the fact that the share of primary products in many countries is much less nowadays than it was in the 1950s, the question is, which of these trends is stronger. Moreover, Cashin and Pattillo (2006) show for Sub-Saharan Africa that the commodity terms of trade have no stable relation with the net barter terms of trade. Therefore it is important to emphasize that what matters for growth and investment is export revenues and therefore the net barter terms of trade (used in our model) and not just one of their components. Moreover, the growth of India and China is part of that of world income, which we will use as an argument in an export demand function. In short, the arguments of Prebisch and Singer - imported capital goods and income and price elasticities of export demand - are still important, but the relevance of primary commodities has diminished in many countries.

As a by-product of our procedure, we also get estimates of total-factor-productivity growth and of scale economies for Brazil, which is the country for which we carry out the estimation. Our theoretical view expressed is that the Solow growth model is a good starting point - simply because investment, population growth and a diminishing marginal product of capital are relevant aspects of growth - but needs modification to grasp the effects of trade.[14]

The paper is set up as follows. In section 2 we present the model and compare it to the neoclassical growth model. Section 3 describes the data. Estimates of the growth model using the general-method-of-moments estimator (GMM) are presented in section

[14] Similar modification of the Solow model can be made for the public sector aspects; see Ziesemer 1990 relating public factors, democracy and growth in a semi-endogenous growth model.

4. In section 5, we use the estimated results to calculate steady-state growth rates, engine and handmaiden effects, and dynamic steady-state gains from trade. Section 6 relates the results to the aforementioned branches of the literature and provides some tentative policy conclusions.

2. The Model

The question dealt with in this section is whether imports of capital goods and low (high) export demand elasticities could account for slow (fast) growth in comparison with the Solow (1956) growth model. The model assumes flexible wages and exogenous employment. A Cobb-Douglas production function with exogenous technical progress is used:

$$Y = e^{bt} A K^{\beta} L^{\alpha} U, 0 < \alpha, \beta < 1, \alpha + \beta \geq (\leq) 1 \quad (1)$$

Y denotes output, *K* capital, *L* labour, *b* the rate of technological progress, 'A' is a time independent constant, U a stochastic term and α and β the elasticity of production of labour and capital. We allow for increasing, decreasing and constant returns to scale. Labour is assumed to grow at rate, ε, which is determined exogenously:

$$L(t) = L(0) e^{\varepsilon t}, \hat{L} = \varepsilon \qquad (2)$$

A "hat" over a variable indicates a growth rate. The fact that they are importers of capital goods seems to be a fundamental problem of developing countries. Importing less luxury consumption goods may be helpful but cannot be a solution by itself. Therefore, it is assumed that no luxury items are imported. Problems referring to the terms of trade or growth may occur despite the absence of imports other than capital goods. Fundamental obstacles for developing economies are rather the importation of capital goods as well as limited export demand. By assumption, capital goods invested in developing countries must be imported:

$$M = \dot{K} \qquad (3)$$

A "dot" over a variable denotes its derivative with respect to time, and M represents imports. Capital goods are the only imports – another simplification besides the absence of foreign debt – and have to be paid for by exports. This requirement stems from the trade-balance equilibrium. Investments are, therefore, limited by exports, denoted by X, which are expressed in terms of the imported capital goods:

$$\hat{K} = \frac{\dot{K}}{K} = p\frac{X}{K} - \delta, \hat{\hat{K}} = \hat{p} + \hat{X} - \hat{K}, \hat{\hat{K}} \equiv d(\log(\hat{K} + \delta))(4)$$

p represents the terms of trade, defined as the price of domestic goods in terms of imported capital goods. Investments need to be paid for by domestic savings measured in terms of imported capital goods. The savings rate s is assumed to be a constant proportion of output in this theoretical part and depreciation is δK:

$$\hat{K} = \frac{\dot{K}}{K} = sp\frac{Y}{K} - \delta, \quad \hat{\hat{K}} = \hat{p} + \hat{Y} - \hat{K} \qquad (5)$$

Investments are limited by exports. Exports in turn are assumed to depend on the trade partners' income, Z, and on the terms of trade, p. For the sake of simplicity, a log-linear export function with a constant B[15] and a stochastic term V is used:

$$X = BZ^{\rho} p^{\eta} V, \rho > 0, \eta < 0 \qquad (6)$$

ρ denotes the income elasticity and η represents the (negative) price elasticity of export demand. Together, these six equations explain the six variables *Y, L, M, p, K,* and *X*.

Inserting the functions for exports and output, (6) and (1), into the export and saving constraint for investment, (4) and (5), respectively, writing the depreciation rate on the left hand side and taking natural logs, denoted *ln*, yields:

$$\ln(\hat{K} + \delta) = \ln B + \rho \ln Z + (1+\eta) \ln p + \ln V - \ln K \qquad (4')$$

$$\ln(\hat{K} + \delta) = \ln s + \ln p + bt + \ln A + (\beta - 1) \ln K + \alpha \ln L + \ln U \qquad (5')$$

Uncertainty is kept as inessential and simple as possible here because we are not interested in any uncertainty aspect per se but rather need this aspect only to relate it to econometric models. Basically, the assumption is that firms know L and K (from the previous period) with certainty and produce after U has become known. Households then decide to save a fraction s of their income Y and this determines gross investment. When the V-term in the export function is known, p can adjust to determine external

[15] A separate estimate of the export demand function in terms of growth rates yields a growth rate of B, which is insignificantly different from zero.

equilibrium. All rigidities and the implied consequences for the future are assumed to be absent for the sake of simplicity. In particular, the irreversibility of capital is assumed to be irrelevant. In a more sophisticated investment theory this is only justified if the optimal capital stock never decreases by more than depreciation.

In our model, the output per worker in units of domestic goods is considered a rough indicator of welfare. The driving forces behind the expected value (denoted by *E*) of the latter are the rate of technical progress and the growth rate of the capital-labour ratio, which is denoted by *k (*with *E(lnU)=0*):

$$\hat{y} = b + \beta\hat{k} + (\alpha + \beta - 1)\hat{L} \qquad (7)$$

The last term corrects for scale economies. Since the rate of technical progress is given, the remaining question is whether a low income elasticity of export demand hinders rapid growth of the capital-labour ratio by restricting the importation of capital goods. The growth rates for the long-term equilibrium growth path are of crucial interest in this respect. Solving equations (4') and (5') for the natural log of the terms of trade and the left hand side variable yields:

$$\ln(\hat{K} + \delta) = \frac{-\ln B}{\eta} + \ln A \frac{(\eta+1)}{\eta} + \frac{\eta+1}{\eta}\ln s + \frac{b(\eta+1)}{\eta}t + \frac{\beta\eta+\beta-\eta}{\eta}\ln K$$
$$+ \frac{\alpha(\eta+1)}{\eta}\ln L + \frac{-\rho}{\eta}\ln Z + \frac{\eta+1}{\eta}\ln U - \frac{1}{\eta}\ln V \qquad (8)$$

$$\ln p = \frac{\ln A - \ln B}{\eta} + + \frac{1}{\eta}\ln s + \frac{b}{\eta}t + \frac{\beta}{\eta}\ln K + \frac{\alpha}{\eta}\ln L - \frac{\rho}{\eta}\ln Z + \frac{1}{\eta}(\ln U - \ln V) \qquad (9)$$

The expected value (setting $lnU = lnV = 0$ for the rest of this section) of equation (8) is a differential equation of K with negative slope. K has an impact on equation (9) but lnp has none on (8).

The next step is to take the derivative with respect to time of both equations, set both sides equal to zero and assume a constant savings ratio in the steady state. Then the steady-state growth rate can be written as follows:

$$\hat{k} = \frac{\rho\hat{Z} - \varepsilon - (1+\eta)[(\alpha+\beta-1)\varepsilon + b]}{-\eta(1-\beta)+\beta} \qquad (10)$$

Inserting this solution into the equation determining the change in the terms of trade and into equation (7) yields the following solutions for the terms of trade and income per capita, respectively:

$$\hat{p} = \frac{(1-\beta)(\rho\hat{Z} - \varepsilon) - (\alpha+\beta-1)\varepsilon - b}{-\eta(1-\beta)+\beta} \qquad (11)$$

$$\hat{y} = \frac{\beta(\rho\hat{Z} - \varepsilon) - \eta((\alpha+\beta-1)\varepsilon + b)}{-\eta(1-\beta)+\beta} \qquad (12)$$

The numerators of equations (10) to (12) consist of three terms, the first of which reflects the "engine of growth" part from the export demand function: the growth rate of world income multiplied by the income elasticity of export demand minus the population growth rate. The product of trade partners' income and income elasticity is the driving force on the demand side. Hence, this part represents the ideas of Prebisch. The last part, on the other hand, captures the handmaiden part (see Kravis 1970). This term supports the view that technical progress leads to an increase in exports via decreased prices if exports are price elastic. Consequently, the causality of this last effects runs from growth to exports, opposite to what the engine of growth supporters propose. Our model contains both parts. Note, however, that the handmaiden part drops out if a country has no technical progress. The third part in the middle of the formulas is only relevant in case of non-constant returns to scale. With increasing (decreasing) returns to scale we have an additional cost reduction (enhancement) which drops out only if $(\alpha+\beta=1)$ in (10)-(12).

The direct effect of technical progress and returns to scale is to decrease production costs and to reduce the terms of trade as can be read off equation (11). The question then arises whether this will cause exports and investments to rise or fall. Assuming exports are price-elastic, there will be an increase in exports and investments as well as in the capital-labour ratio in equation (10). If exports are price-inelastic, however, technical progress has a negative impact on the growth rate of the capital-labour ratio. Considering the growth rate of income per capita, it is obvious that technical progress has not only a direct but also an indirect effect on this variable. The latter effect is due to changes in the capital-labour ratio induced by technical progress. The direct effect outweighs the indirect one so that technical progress always has a positive impact on real wages.

Summing up, technical progress and returns to scale have a negative impact on the terms of trade while they influence per capita income positively. The higher the income elasticity the higher the growth of export demand for any growth rate of world income and the higher the growth rate of capital imports in equation (10). The latter aspect causes income in equation (12) to grow at a higher rate and the growth rate of the terms of trade is driven up as well. A higher growth rate of income in the trade partners' countries will lead to an increase in exports. Yet, a critical point is whether the change in income multiplied by the income elasticity, $\rho\hat{Z}$, exceeds the population growth rate ε. This difference governs the growth rate of the capital-labour ratio in equation (10) in case of constant returns to scale and absence of technical progress. If the income elasticity of export demand is low and the population growth rate is high, the effect on the growth rates concerning the terms of trade, the capital-labour ratio, and income per capita will be negative.

In conclusion, the terms of trade will fall on condition that the rate of technical progress and scale economies is not exceeded by a large difference between the export growth rate and the population growth rate in equation (12). The growth rates of the capital-labour ratio and income per capita may be negative because of low income and price elasticities. With respect to income elasticity and trade partners' income growth, the terms of trade are an indicator of economic development because they boost both, per capita income and the terms of trade.

Comparison with the Results of the Solow Growth Model

The Prebisch-Singer thesis poses the task of presenting trade conditions which result in a slower growth rate for the main economic indicators of welfare than in the Solow model. Considering a Solow model with a constant-returns-to-scale production function like equation (1), the capital-labour ratio and per capita income grow at the same rate, $b/(1-\beta)$. In the model examined above, this result can be obtained by means of taking into account two special cases. First, equation (12) can be written in the form:

$$\hat{y} = \frac{b}{(1-\beta)}\{1 - \frac{\beta}{[\eta(1-\beta)]}\} + \frac{(\rho\hat{Z} - \varepsilon)\beta}{[-\eta(1-\beta)+\beta]}, \qquad (12')$$

For any value of $\rho\hat{Z}$, it holds that $\hat{y} = b/(1-\beta)$ assuming that η approaches minus infinity. This is the small country case in neoclassical models. Second, it can be shown that $\hat{y} = b/(1-\beta)$ and $\hat{p} = 0$, both if $\rho\hat{Z} - \varepsilon = b/(1-\beta)$, just like a closed economy in the Solow model. Then, the engine of growth, $\rho\hat{Z} - \varepsilon$, has the same effect as the handmaiden part, $b/(1-\beta)$, and therefore, the growth rate coincides with that of the Solow model.

Figure 1 presents $\hat{y}$ as a function of ρ for different values of η under the assumption – made to emphasize the role of the income elasticity – that $\hat{Z} = \varepsilon + b/(1-\beta)$ and of constant returns for both models because the Solow model is normally presented in this way. The vertical intercept increases with the price elasticity of exports. The slope, on the other hand, is less steep the more price-elastic exports are.

FIGURE 1 OVER HERE

Due to equation (12'), there is one straight line for each value of *η,* being equal to $b/(1-\beta)$ at $\rho = 1$. The horizontal line represents the small country case with the price elasticity being equal to minus infinity. It shows that in this case exports constitute no constraint to growth, a conclusion that is in line with traditional neoclassical thinking. Figure 1 reveals that the capital importing economy grows at a lower rate than in Solow's model if the income elasticity is lower than one. For income elasticities greater than one, the economy grows faster than predicted by the Solow model. These conclusions do not hold for a price elasticity of minus infinity, since this is the small country case.

In view of the interplay between the growth rate of the terms of trade and the income elasticity of export demand, a similar graph is drawn in figure 2. The less price-elastic exports the steeper the slope and the more negative the vertical intercept. For income elasticities smaller than one, the growth rate of the terms of trade fall and real wages grow at a lower rate than in the Solow model. There is, thus, a close relationship between the latter two variables. The driving force behind both of them is the income elasticity of export demand. The effect of the latter is reinforced by a lower price elasticity of export demand. The obvious corollary is that of a high price elasticity weakening the impact of the income elasticity of export demand on the developments of real income and the terms of trade. As in the previous graph, the relationship is drawn for $\hat{Z} = \varepsilon + b/(1-\beta)$ and alternative values for the price elasticity. To summarize, the price and income elasticities of export demand are crucial determinants for a developing country's growth prospects.

FIGURE 2 OVER HERE

In this model the importation of capital goods and low (high) elasticities of export demand contribute to explaining the slow (fast) growth of developing countries. The question now arises whether these price and income elasticities are indeed low. That issue is taken up in the following sections.

Again, we would like to point out the simplifying assumptions we have made: absence of domestic capital goods, imported consumption goods, foreign debt, and unbalanced trade. None of these assumptions holds exactly true for Brazil as can easily be seen by examining the World Development Indicators.[16] Whether or not the

[16] For Brazil, Gross fixed Capital formation (GFCF) is about twice as large as total imports. For 1995 (but not for other years) we can calculate from the WDI that production of machinery and transport equipment is about $US 38.1 billion. This is about 25% of GFCF. However, of these $US38mln, 8.8 are exported, leaving about 29 for domestic investment. On the other hand, 21 are imported according to the UN Intern.

abstraction is *too* strong will be revealed by the econometric work. After all, the Solow growth model, which is widely used in empirical work, is a special case of our model. The former ignores imported inputs and the exports used to pay for them, whereas we ignore that a large part of capital goods is produced domestically. Furthermore, past empirical studies estimating export demand income and price elasticities use a similar export demand function but do not make use of a growth model for the supply side as we do. Integrating all of these neglected aspects in a fully-fledged model would require the estimation of many more parameters with a small number of observations. Therefore, it is not necessarily a drawback to use this simple model. In a model including domestic capital goods, these would have to grow at a rate that is proportional to that of foreign capital goods in order to avoid running too much into decreasing returns to the accumulation of one of them only. Absence of debt is dealt with by using the investment/GDP ratio rather than the savings ratio. Khan and Knight (1988), and Esfahani (1991) also assume all imports to be inputs. It can only be hoped for that the other aspects would merely change the intercept of the regressions below. This is a matter left for future work.

We have made strong claims in the introduction in regard to the relevance of this model when compared to other models. Therefore this model should be estimated and tested. In order to do so, we should stick as closely as possible to the model because other specifications might be too general and impossible to be interpreted as support for the model. Moreover, for the calculation of long-run values using the model in section 5, we

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Trade Statistics Yearbook, indicating that about 42% of machinery and transport equipment is imported provided it is not re-exported. Unfortunately it seems impossible to construct separate stocks of domestic and foreign capital without having similar information for other items and periods of GFCF than just machinery and transport as of 1995.

need the values of the parameters as obtained from an estimate of the model. Therefore the equations estimated in section 4 are (8) and (9). Other types of purely empirical regression equations would not yield estimates of all of these parameters. Note that these equations hold for both, the steady state and the transition path. We want to estimate the equations as a simultaneous system. Once one equation is estimated, it is obvious that all parameters can be identified. Therefore, we have one constraint per regressor except for the intercept and the world income variable, which has the same coefficient in both equations.

3. The data

We decided to carry out the empirical estimation for Brazil for several reasons. First, the model is dynamic in nature and all parameters are likely to have country-specific values. Therefore we focus on a time-series estimate for just one country. Second, we like to consider a large country in order to avoid strong dependence of the results on single products, which one often finds for small countries. Third, for Brazil the data availability is better than for other countries we have checked. This is not meant to say, though, that similar estimates cannot be done for other countries as well, but the problems in regard to the number of observations will be greater. In order to estimate the equations, time series for the savings or investment/GDP ratio, capital, trade partners' income, the terms of trade and employment are required.

The data for gross fixed capital formation as percentage of (GDP minus depreciation) are taken from the World Development Indicators 2004 and represent investment. They stem from the World Bank national accounts following the SNA (System of National

Accounts of the UN) conventions. We make use of this figure instead of the savings ratio in order to account for that part of investment financed by foreign debt, which is ignored by our model.

The data for capital are constructed by cumulating Gross Fixed Capital Formation after subtraction of the data for depreciation, starting from an initial value determined according to the formula[17]

$$K_0 = \frac{I_1}{\left(\hat{K}_1 + \delta\right)}$$

Depreciation is assumed to be 3.7% of capital for all periods because this is the average value of available figures in earlier national accounts data. For I_1 we use gross fixed capital formation as of 1970. The initial growth rate of the capital stock in the above formula is assumed to be .1, which corresponds to the order of magnitude of the growth rates of GDP and employment in those years. With the capital stock obtained in this way we can determine growth rates as log differences and add the rate of depreciation to get the dependent variable of equation (8).

The employment data are taken from the ILO website. These are numbers of employed persons irrespective of the number of hours worked. The time series starts in 1972 but values for the years 1974, 1975, 1980, 1991, 1994, 2000, 2001 are missing. We do not try to interpolate them because in an earlier attempt we found that different ways of doing so have an impact on the unit root properties of the time series.

[17] See Verspagen (1995) for an extensive explanation.

Trade partners' income is taken to be world income since Brazil is trading with all the countries in the world. The world income is the sum over the GDP in constant 1995 US dollars of 208 countries, of which some do not provide these data though.

The terms of trade are calculated as 'Exports as capacity to import' divided by 'exports of goods and services', both in terms of constant local currency units.[18] Exports as a capacity to import equal the current price value of exports of goods and services, deflated by the import price index. They stem from the World Bank national accounts and we took them from the World Development Indicators.

4. Econometric methods and estimation results for the system of equations

Econometric methods have been developed traditionally either for stationary variables and more recently for variables being integrated of order one, I(1). Before discussing the methods we check whether the time series follow unit root processes and determine the order of integration of the variables. Testing for unit roots suffers from the fact that these tests have been designed for a large number of observations whereas we deal with only a few observations. Hence, the tests have low power. For world income the ADF test does not reject the unit root hypothesis. The other variables do not follow unit root processes according to the ADF test. Consequently, we use equations (8) and (9) with only one modification: we replace *lnZ* by *d(lnZ)*t*, which can be based on rewriting the export function as $X = e^{\rho d \ln Z * t} p^{\eta} = Z^{\rho} p^{\eta}$. The latter version of the variable does not have a unit root according to the standard ADF test. So we can use equations (8) and (9) in their current form.

[18] Data are available in the appendix to the working paper version.

The system has three important properties. First, there are constraints on the coefficients, generating a non-linear problem of estimation. Second, both equations of the system contain the random terms from the production function and the export function and therefore the residuals of the two equations will not be independent. These two properties together suggest using the seemingly unrelated regression (SUR) method. Third, equation (8) is a differential equation. Residuals have a positive impact on the dependent variable, enhancing the capital variable on the right hand side in the next period. As this is a stock variable, the effect is permanent. In other words, the residuals have an impact on all future variables of capital and the regressor in the first equation is not exogenous although it is predetermined (see Davidson and Mackinnon 2004, chapter 3.2). As this would bias the estimates, we use the generalized method of moments (GMM-HAC with heteroscedasticity and autocorrelation correction of the coefficient standard deviations) including all regressors and lagged variables of capital as instruments to correct for endogeneity. The GMM-HAC estimator corrects the standard deviation but a serial-correlation bias of the coefficients cannot be excluded. Therefore we present estimates with and without autocorrelation correction. We present the first GMM estimate without autocorrelation correction in the first column of Table 1. Table 1 shows the formulas and the values of the coefficients of regression equation (8) from which the parameters of the model can be inferred. The coefficients of equation (9) are non-linear formulas of these coefficients.[19]

TABLE 1 OVER HERE

[19] See unpublished Appendix to the working paper version for the implemented version of the two equations.

The over-identifying constraints for the additional instruments require that the product, *nJ*, of the J-statistic and the number of observations, *n*, are chi-square distributed. The value *nJ* in Table 1 has to be smaller than the critical value for the relevant degrees of freedom reproduced in the Table as c(d.f.). As there are four constraints in the two equations, we have at least four degrees of freedom. However, the number of lagged instruments has to be added for the chi-square test (see Greene 2003, p.548/9), which is passed at the 5% significance level for the three regressions of Table 1.

TABLE 2 OVER HERE

In the first regression, the income elasticities of export demand (0.19) is at the lower end of the range of earlier estimates and the price elasticity (-1.86) is larger in absolute terms than in previous studies (see Table 2 for a comparison). The time trend representing technical progress is significant and has the expected sign. The rate of total factor productivity growth is about 2%. Given the elasticity of production of labour of about .5, the labour augmenting rate of technical change is 4%. This figure is a bit larger than in estimations assuming constant returns to scale. However, the sum of the elasticities of production is .81 < 1 and indicates decreasing returns to scale at a measure of .19. If we arbitrarily (and therefore not shown) drop the time variable, we get increasing returns to scale. As shown above, the Solow growth model is a special case of our model if the price elasticity is equal to minus infinity. This would require c(2)=1. Given the high significance of the value around 0.5 it is clear that the alternative (to our model) hypothesis of the Solow model will be rejected by an F-test. The formulas for the identification of the parameters of the production function indicate that the estimated coefficients have to be in narrow ranges in order to get reasonable parameter values for the model. In this sense the estimate for the system is quite encouraging. The only trouble here comes from the serial correlation as indicated by a very low DW statistic[20]. The standard procedure is to add lagged dependent variables to the regression equation(s). The result of adding one lag in each equation is shown in the second equation in Table1. The income and price elasticity of export demand is slightly higher now, at *.33*. The price elasticity has doubled and is now *-4.9*. The growth rate of total factor productivity is now much smaller at about 1%. The decreasing returns measure is still .19 because the elasticity of production of capital is enhanced at the cost of that of labour. There still may be some autocorrelation in the first equation. We save the residuals from the previous (second) regression and add their lagged values to the regression (also as instruments). This carries out the standard Breusch-Godfrey test after application of the Frisch-Waugh-Lovell theorem saying that the lagged residuals can be added to the regression equation to test for serial correlation (see Davidson and MacKinnon 2004). The third regression in Table 1 shows the result that we still have some autocorrelation as can be seen from the significant coefficient of the lagged residuals. Due to this last step of including lagged values of the residuals five observations are lost, leaving us with a test of low power. [21] However, with lagged residuals in the regression the estimates of the third regression are inconsistent as an estimate of the model, because lagged instruments can only mitigate but not completely remove the inconsistency[22] and inference of parameters values is therefore invalid. This regression then is at best valid as a Breusch-Godfrey test for serial

[20] Below we will also employ the Breusch-Godfrey test because of the endogeneity problem discussed earlier, because the DW statistic is not the adequate tool in case of endogeneity.

[21] Panel data are not a way out for the low number of observations in our case, as at least income and price elasticities of export demand and TFP growth rates will not obey the homogeneity assumption and therefore lead to biases.

[22] We are grateful to Pierre Mohnen and an anonymous referee for pointing this out to us.

correlation; the reservation coming from the low number of observations. Using the second regression seems then to be more appropriate. If we except regression three as an autocorrelation test, this means that we have a serial correlation bias in the second regression. However, we take it from a similar problem in Epple and McCallum (2006, p.376/7) that the Durbin-Watson statistic for both equations of regression two is in a region where we do not have to worry about the bias, because it is likely to be small. For regression two to be consistent we have to assume that it has no autocorrelation, which means that we need to reject regression three as an autocorrelation test, because of the low number of observations. Using the second regression in Table 1 as our best result is done therefore at the risk of having some bias and some inconsistency, or assuming absence of serial correlation in spite of regression three. Future work therefore should concentrate on model variants that are better able to capture cycles. In spite of all these problems it is worth pointing out that we get the expected signs and all coefficients are significant at the seven percent level in spite of a low number of observations.

5. Steady state growth rates, engine and handmaiden effect, and dynamic gains from trade

We have estimated the model for its non-steady-state version. For long-run predictions, the theory gives us the steady-state formulas for growth rates of expected values. Note that in the estimated parts of the model, no use was made of the assumption of perfect competition, which is not in accordance with increasing returns to scale. In this section, we calculate the steady-state growth rates for equations (10)-(12) numerically so as to specify the long-run predictions of the estimated models. We define the engine and handmaiden effects and calculate their values in order to compare them to each other and in order to compare them to the effect export growth rates have on GDP per capita growth rates in the survey of Lewer and van den Berg (2003). Finally, we calculate the corresponding growth rates of the Solow growth model as well as the difference between the predicted growth of our model and that of the corresponding Solow model as the dynamic gains from trade.

TABLE 3 OVER HERE

In Table 3, we report the steady-state results for the growth rates of *k, p* and *y*. Additionally, the following effects – extracted from equations (10)-(12) – are presented: *g (m, s)* indicates the engine (handmaiden, scale) effect, obtained as the derivative of the formula for the growth rate of *y* with respect to the growth rate *dlnZ (b, dlnL)*.

$$g = \frac{\beta\rho}{\beta(\eta+1)-\eta}, m = \frac{-\eta}{\beta(\eta+1)-\eta}, s = \frac{-\eta(\alpha+\beta-1)}{\beta(\eta+1)-\eta}$$

The scale effect is the effect of *dlnL* only to the extent that it would drop out if there were constant returns to scale. Next, *x* represents the corresponding GDP per capita growth rate of the Solow model under the assumption that its parameters are identical to those of our estimates. Finally, the difference in the growth rates of our model, *dlny*, and the corresponding Solow model, denoted as *t*, is defined as the dynamic steady-state gains from trade. The parameter values are those from the second equation of Table 1.

$$x = \frac{b+(\alpha+\beta-1)\varepsilon}{1-\beta}, t = d\ln y - x$$

All calculations are done under the assumption that world income will continue to grow at *2.6%* in the steady state. Finally, we need an assumption for the growth rate of employment. This rate was anything but constant in the past as can be seen from the following regression:

$$\ln L = 9.71 + .06t - .00057t^2$$
$$(212)\ (17.2)\ \ (-9.16) \quad \text{adj.}R^2 = .993$$

A plot of the regression result and its time derivative representing the growth of employment appears in Figure 3. The result indicates that the growth rate of labour drops to zero at time $t>50$, which is after the year 2010.

FIGURE 3 OVER HERE

The results are as follows.[23] The steady-state growth rates of capital and income per capita are positive only if employment growth is sufficiently small, at about one or two percent respectively. This is due to the low income elasticity of export demand and technical progress being diminished by the negative scale effect. The strongly positive growth rates of the past with non-zero population growth are therefore generated by the transitional growth of capital accumulation. The terms of trade are falling – as the data reveals for the past – because the growth of the supply force, employment (multiplied by the decreasing returns measure) plus technical change, is larger than that of the demand force, world income multiplied by the income elasticity. The handmaiden effect, $m=1.39$, is larger than the engine effect, $g=.033$, and the scale effect, $s=-.27$, again because the income elasticity of export demand is low. The handmaiden effect multiplied by the rate of technical change, $m*b$, is larger than the total engine effect expressed as $e = \dfrac{\beta(\rho\hat{Z} - \varepsilon)}{-\eta(1-\beta)+\beta}$, even for the lowest rates of population growth. With lower population growth, this latter effect gets larger (see third but last line in Table 3) and the scale effect vanishes (last line of Table 3), whereas the handmaiden effect is independent of population growth. We also would like to emphasize the importance of the price elasticity. The denominator of the engine, handmaiden and size effects is the same as that of the steady-state growth rates in equations (10)-(12). Under the parameter values obtained from the second regression it has a value of about *3.55* compared to $1\text{-}\beta = .65$ under autarky. Under the more traditional estimate of a price elasticity of minus one it would have the value unity. The denominator is much larger now. But the price elasticity is also multiplied to the scale effect and the rate of technical change. They are also enlarged now, except for the engine effect and the terms of trade formula, where it does not appear in the numerator. A high price elasticity of almost minus five is working towards a dominance of the handmaiden and the scale effect.

The closed economy growth rate is driven by decreasing returns to scale, employment growth and technical change. The lower future employment growth the higher is the hypothetical autarkic growth rate. The steady-state part of the dynamic gains from trade becomes almost zero as employment growth goes to zero. Lewer and van den Berg (2003) illustrate that dynamic gains from trade are large when export growth rates are high in the transition after taking policy measures. Therefore, static gains from trade and the ones during transition may be larger than those in the steady state even if the latter are negative.

[23] The results are very similar to those obtained from using the parameters from the third regression as the income elasticity of export demand is low in both regressions and technical change is larger in the second

6. Conclusion

The introduction has pointed out that the modified Bardhan/Lewis model is the only one that has income and price elasticities of export demand in the long-run growth formula. Therefore this model is particularly well-suited to understand and contribute to the literature on export and growth, the Prebisch-Singer thesis, and dynamic gains from trade. As we have made strong claims in regard to these strands of literature and alternative models, the model should be estimated and tested. We believe that any regression that is less closely tied to the model would not really test the model. The estimates suffer from a low number of observations and an autocorrelation bias cannot be excluded but is likely to be small. The estimated values for the parameters of the production and export functions for Brazil are very plausible and therefore provide some support for the model. This allows us to draw the following conclusions.

From the perspective of the exports and growth literature, the model adds economic causality to the econometric Granger causality of the literature in the sense of estimating a growth model that contains an economic mechanism turning world income growth through exports via imported inputs into growth. An explicit model that can provide a causal explanation can be estimated and tested. The low number of observation and possibly the serial correlation allow for some doubts in regard to a bias and inconsistency in the parameters. But getting expected signs and reasonable orders of magnitude reasonable and a significance at the seven percent level obtained provides some support for the model.

From the perspective of the Prebisch-Singer literature, the results clearly demonstrate that income and price elasticities of export demand may be important for the growth of

regression at the cost of obtaining deceasing rather than constant returns to scale.

Brazil in the period we have considered. If population growth is low enough, the theoretical model allows for positive per capita income growth through technical progress, imported capital goods, positive dynamic gains from trade and changing terms of trade. However, if employment growth is large, negative rates are also possible. According to our estimates, the income elasticity is small, thus hampering growth and driving down the terms of trade in line with the Prebisch's expectations. However, the effect is only weak due to a relatively high price elasticity of export demand, which translates the falling terms of trade and therefore the scale effect and technical progress into a high export demand as expected by Kravis. Both arguments interact and are quantitatively relevant. According to our model, neither of the two can be dismissed because technical change matters on the supply side and exports are important determinants on the demand side. In addition, decreasing returns seem to play a role that was underemphasized so far in the literature as opposed to the classical economists.

The steady-state part of dynamic gains from international trade is dependent on the magnitude of employment growth: high employment growth yields negative dynamic gains from trade in the steady state whereas low employment growth brings about positive gains from trade if the income elasticity of export demand is high enough and the price elasticity low enough. If employment continues to grow at such a high rate as in the past, dynamic gains from trade will be negative in the future. But the trend in employment data points to the opposite direction. As population growth approaches zero, gains from trade also go to almost zero although world income growth and technical change (plus scale effect) multiplied by the price elasticity translate into higher demand for exports. The reason is that the high price elasticity enhances the denominator of the major effects more strongly (from 2/3 under autarky to 3.55 under trade) than the numerator and therefore reduces both effects.

In regard to policy we would like to emphasize that the implementation of WTO agreements is not costless (Rodrik 2000, p.13). Therefore trade reforms have to be compared to their opportunity costs and benefits from other political decisions on investments like improvements of institutions and human capital investment. In these analyses it should be taken into account though, that gains from trade are not only static but rather dynamic. In particular, we speculate that investments increase with trade volumes and therefore trade liberalization may enhance transitional growth rates and long-run levels, both depending on the income and price elasticities of export demand. In short, the dynamic theory and empirics of trade and growth should be included in comparative cost-benefit analyses. But these suggestions require further research on the links from trade liberalization to growth as contributions to cost-benefits analyses.[24] For the time being it therefore seems to be most adequate not to put all eggs into one basket and to pursue a balanced strategy of improving institutions, factor accumulation, technical change and trade relations, the latter focussing in a balanced way on black market premia, other macroeconomic issues and trade liberalization. Given the slow pace of trade negotiations this should leave ample opportunity for the other measures.

[24] We want to thank Harry Bloch and Bart Verspagen and two anonymous referees for useful comments on an earlier version and Abraham Garcia, Clemens Kool, Pierre Mohnen, Franz Palm, Jean-Pierre Urbain for useful talks. Responsibility is entirely ours.

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Table 1: Regression results for the system of equations

Variable	Method *Coefficient of 1st eq.*	GMM [a] *Coeff (t-val)*	GMM [d] *Coeff (t-val)*	GMM [e] *Coeff (t-val)*
constant of 1st eq.		19.23 (10.51)	15.19 (8.76)	15.18 (5.24)
constant of 2nd eq.		7.23 (3.16)	2.73 (3.21)	3.73 (3.20)
lns	$c(2)=(\eta+1)/\eta$	0.46 (12.59)	0.80 (25.04)	0.74 (23.33)
t	$c(3)=b^*(\eta+1)/\eta$	0.01 (2.89)	0.01 (2.24)	0.0025 (.53)
lnK(-1)	$c(4)=(\beta\eta+\beta-\eta)/\eta$	-0.85 -(7.60)	-0.72 -(7.04)	-0.79 -(5.03)
lnL	$c(5)=\alpha(\eta+1)/\eta$	0.23 (1.56)	0.36 (1.87)	0.5228 (1.88)
dlnZ*t	$c(6)=-\rho/\eta$	0.10 (4.32)	0.07 (5.63)	0.07 (3.24)
lnkhatplusd(-1)		-	0.25 (7.16)	0.13 (2.57)
lnp(-1)		-	0.73 (13.46)	0.69 (13.09)
lagged residual				0.72 (3.08)
adj.R-sq. (1st/2nd eq.)		0.88/.74	0.96/.87	.96/.87
No.obs, n, (1st/2nd eq.)		22/24	22/24	17/24
J statistic for system		0.32	0.46	0.45
nJ<c(d.f.) [b]		22x.32<18.31(10)	22x.46<18.31(10)	17x.45<19.68(11)
nJ<c(d.f.) [c]		24x.32 < 9.49(4)	24x.46<14.07(7)	24x.45<14.07(7)
Durbin-Watson		1.06/.88	1.52/2.25	2.04/2.24
Identified parameters				
prod.elas.labour α		0.492	0.456	0.71
prod.elas.capital β		0.316	0.353	0.29
tot.faact.prod. gr.b		0.021	0.0096	0.00345
exp. inc.elas. ρ		0.193	0.328	0.25
exp.priceelas.η		-1.86	-4.94	-3.82
intial prod.level A		1.63x10exp(5)	2.6x10exp5	93504
exp.level param. B		1.14x10e11	1.83x10e11	1.48x10e11

(a) Instruments: regressors and lnk(-2) to (-7) in the first equation and none in the second.
(b) c(d.f.) is the critical value for degrees of freedom indicated in brackets for the first equation at the 5% significance level of the chi-square test for the over-identifying constraints of the estimates; degrees of freedom is number of constraints, which is 4, plus number of lagged instruments.
(c) c(d.f.) is the critical value for degrees of freedom indicated in brackets for the second equation at the 5% significance level of the chi-square test for the over-identifying constraints of the estimates; degrees of freedom is number of constraints, which is 4, plus number of lagged instruments.
(d) Instruments: regressors and *dlnk(-1) to (-5)* and two lags of the dependent variable in the first equation and *lnp(-2)* to (-4) in the second.
(e) Instruments as in previous regression plus lagged residual regressor.

Table 2: Overview of income and price elasticities of export demand for Brazil

Year	Author	Period	y	pm/pd	pm	pd
1969	Houthakker, Magee	1951-1966	0,34	-0,39		
1976	Lemgruber	1965-1974	1,97*	-0,41*		
1984	Aggarwal	1969-1978	0,253*	-1,23*		
1986	Bahmani-Oskooee	1974:1-1980:4	0,007	-0,151		
1988	Zini	1970:1-1986:3	0,690*		-0,171*	0,131
1992	Faini, Pritchett, Clavijo	1967-1983	0,60*	-1,51*		
1993	Bairam	1964-1985	3,93			
1995	Reinhart	1970-1991	2,447	-0,148		

y: foreign market income
pm: import unit value index
pd: domestic producer price or wholesale index
*: significance at 5% level
Source: Bairam (1988), Fullerton et al. (1999), Houthakker and Magee (1969), Reinhart (1995).

Table 3
Calculated steady-state growth rates, engine, handmaiden and scale effects and dynamic gains from trade for alternative values of labour growth

dlnL	0.02850	0.02000	0.01000	0.00500	0.00100	0.00000
dlnk	-0.00101	0.00318	0.00812	0.01059	0.01256	0.01306
dlnp	-0.00481	-0.00372	-0.00244	-0.00179	-0.00128	-0.00115
dlny	0.00380	0.00690	0.01056	0.01238	0.01385	0.01420
g	0.03262	0.03262	0.03262	0.03262	0.03262	0.03262
m	1.39130	1.39130	1.39130	1.39130	1.39190	1.39190
s	-0.26585	-0.26585	-0.26585	-0.26585	-0.26585	-0.26585
x	0.00642	0.00893	0.01189	0.01336	0.01454	0.01484
t	-0.00263	-0.00203	-0.00133	-0.00098	-0.00070	-0.00063
e	-0.00199	-0.00114	-0.00015	0.00035	0.00075	0.00085
m*b	0.01336	0.01336	0.01336	0.01336	0.01336	0.01336
s*dlnL	-0.00758	-0.00532	-0.00266	-0.00133	-0.00027	0.00000

Figure 1: The Relationship between the Growth Rate of per capita income and the Income Elasticity of Exports (for various Values of the Price Elasticity)

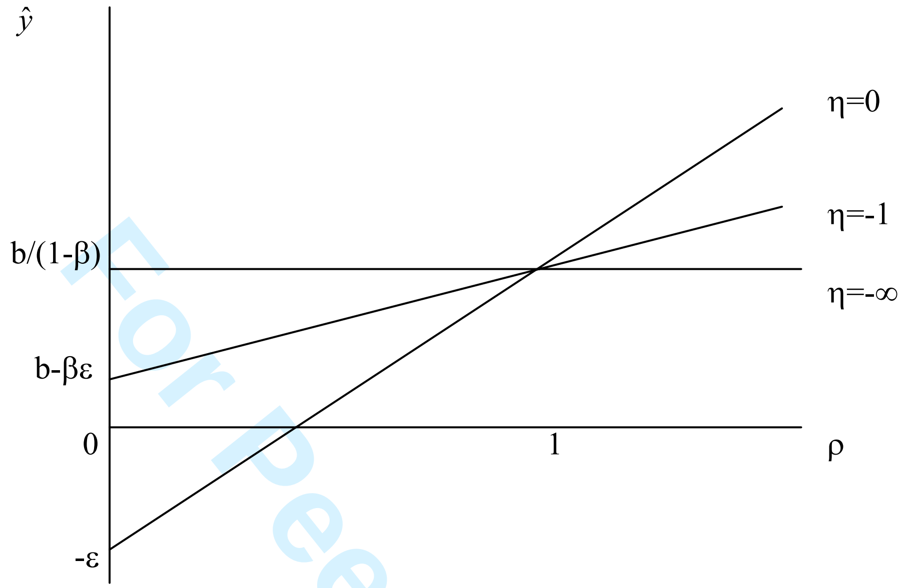

Figure 2: The Relationship between the Growth Rate of the Terms of Trade and the Income Elasticity of Export Demand (for various Values of the Price Elasticity)

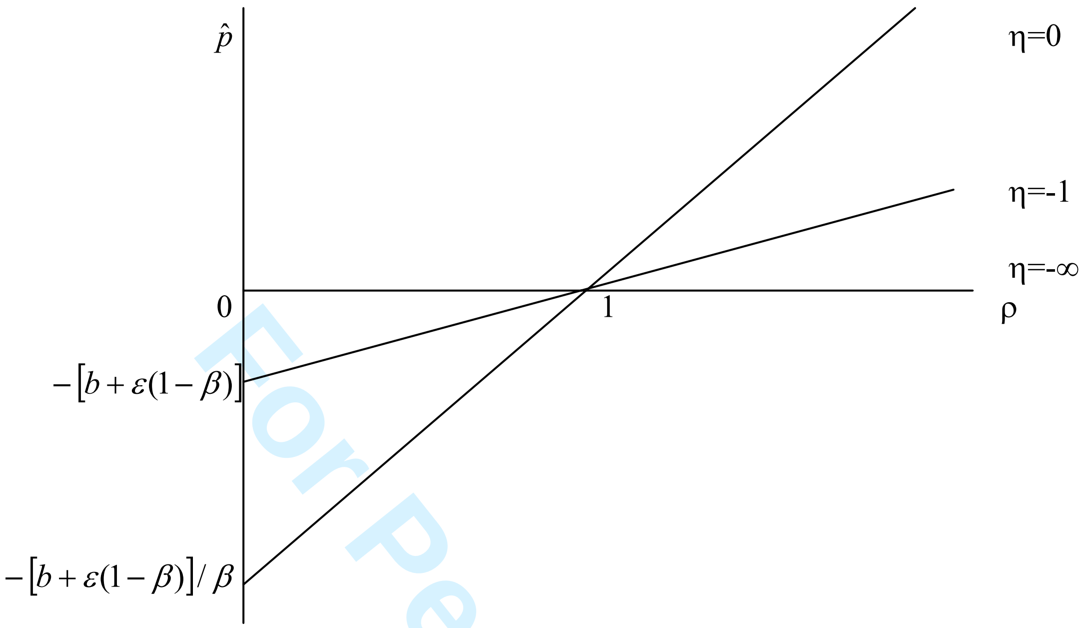

Figure 3: Plot of employment (in natural logs) and its growth rate