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A semi-endogenous growth model for developing countries with public factors, imported capital goods, and limited export demand

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A Semi-endogenous growth model with public factors, imported capital goods, and limited export demand for developing countries

Abstract We build a semi-endogenous growth model for developing countries with non-rivalrous public factors, imported capital goods and an export demand function. The model exhibits the three-way interaction between public and private investment and trade shown recently in the empirical literature and also here for Sub-Saharan Africa. Pritchett's (2000) government investment inefficiency parameter has transitional growth effects distorting between public investment and private capital, consumption and exports, the latter biasing the terms of trade. Our analysis of a vector-error-correction model (VECM) for Trinidad &Tobago shows that additional expenditure for public investment increases output less than taxes decrease per capita consumption and therefore is sub-optimal there. Both, temporary and permanent shocks on public investment have level effects supporting semi-endogenous growth modelling and demonstrate that the VECM effects are in line with the logic of the theoretical model; terms of trade are endogenous.
JEL code: F43, H54, O41, O54.
Keywords: Semi-endogenous growth; open economy; public investment; human capital; VECM.

1. Introduction

Closed economy or small open economy growth models tend to underemphasize three important phenomena. First, many countries import almost all of their capital goods, which have to be paid for by exports either immediately or later if debt is incurred. Second, models with small country assumption, defined as given terms of trade, underestimate the sources and effects of changing terms of trade, and thereby the price mechanism. Third, public investment has non-rivalrous properties and governments have to find the optimal level of taxation and public investment. Whenever a model in the literature takes one of these problems into account it ignores the other two. The interaction of public capital, imported capital goods, export demand and the basic properties of growth models like population growth, investment and human capital accumulation is therefore not considered. To address this gap in the literature, the first purpose of this paper, we expand a human capital augmented Solovian growth model similar to that of Mankiw et al. (1992) with imported capital goods, limited export demand and endogenous terms of trade as in Bardhan and Lewis (1970)[1] and non-rivalrous[2] public factors as in Ziesemer (1990). As a consequence, long-run growth rates depend not only on exogenous technical progress, but also on world income growth, income and price elasticities of export demand, the growth rate of the number of persons with access to education and the elasticity of production of public factors in human capital. The non-rivalrous character of public factors and endogenous terms of trade can both generate semi-endogenous growth and do so also when modelled

[1] Khang (1968) has a similar model but associates it with imported raw materials. Whereas in Acemoglu and Ventura (2002) an endogenous growth mechanism is dampened by falling terms of trade leading to a falling value of the marginal product of capital, in the models of Khang (1968) and Bardhan and Lewis (1970) terms of trade growth enlarges (diminishes) the growth rate of the Solow model if the speed of growth of supply is lower (higher) than that of demand and therefore we find semi-endogenous growth in these models.

[2] Many other papers follow Barro (1990) where the public factor enters the production function in the same way as capital and labour, and therefore could be privatized, which is less obvious for non-rivalrous factors. Duran-Fernandez and Santos (2014) are an exception in that the public factor is regional and non-rivalrous regarding subsectors. In Chakraborty and Dabla-Norris (2011) they are non-rivalrous factors in regard to firms, taxed households are identical (avoiding tax conflicts), and the major problem discussed is one of a benevolent government auditing corrupt bureaucrats to ensure the quality of public capital.

jointly. Transitional growth consists of a system of three central differential equations in private capital, human or public capital and the terms of trade. The model is intended to capture the growth forces of countries with little or no R&D so that endogenous growth through R&D production functions is ignored.[3]

In principle, this model can be estimated in several ways. Depending on the choice of method like a linear vector-error-correction model letting the data speak and lags taking care of non-linear developments, or non-linear estimation of the equations and parameters as they come out of the theory, the estimation is more or less closely related to the model. We apply a vector-error correction model (VECM) to Trinidad and Tobago, which has achieved the level of a high-income country recently without a prominent role of R&D (Mohan et al. 2014). We add, as a second purpose of this paper, to the literature using dynamic simultaneous equation models in the analysis of public investment in developing countries containing the early contributions of Canning and Fay (1993), and the more recent ones by Ferreira et al. (2006), Canning and Pedroni (2008), Sahoo et al. (2010), Agénor and Neanidis (2015) and Fosu et al. (2016). Dynamic approaches are able to distinguish short and long-run effects of public investment and other variables (Glomm and Ravikumar 1997) and take dynamic feedback from and to other variables into account (de Frutos and Pereira 1993). Moreover, the VECM deals adequately with the basic econometric problems discussed in the early surveys on public capital and growth: common trends, energy prices, causality, non-stationarity and cointegration, and simultaneity (see de Frutos and Pereira 1993, Gramlich 1994; Glomm and Ravikumar 1997).

Earlier literature has focussed on the effects of public investment or capital or (combinations of) physical and quality indicators on output or its growth (see Canning and Fay (1993), Glomm and Ravikumar (1997), Sanchez-Robles (1998), Calderón et al. (2015), Agénor and Neanidis (2015)) at various regional or sectoral levels (Duran-Fernandez and Santos 2014). In contrast, we think, similar to Fosu et al. (2016), that consumption per capita rather than GDP per capita should be considered; of course, both are positively related to utility and welfare. Consumption equals output diminished by public investment (or taxes) and exports. For economies without a machinery sector, exports are used for importing private investment goods. A possible outcome, found in our application for Trinidad and Tobago, is then that public investment may stimulate private investment and enhance the GDP; but consumption per capita may be decreased - unlike Sub-Saharan Africa according to Fosu et al. (2016) - if the effect on GDP per capita on disposable income is lower than that of taxation.[4]

In our paper, the two-way feedback relation between exports and public investment is new in the theoretical growth model as well as the empirical part.[5] It therefore can integrate theoretically and

[3] Growth with R&D of domestic firms at the technology frontier, which is typical for some of the less poor developing countries, is considered by Gersbach et al. (2013) in connection with foreign firms rather than trade elasticities. China is the poorest country in their sample.

[4] Closely related, Shi and Huang (2014) find too high public relative to private capital in China according to the criterion that both should have equal marginal value products.

[5] For the relation between growth and exports van den Berg and Schmidt (1994) as well as Hatemi-J and Irandoust (2000) provide error-correction models.

empirically, as a third purpose of the paper, some recent insights on the relation between infrastructure and trade volumes, mostly estimated via the gravity model, and link it to per capita income growth. The whole literature on the infrastructure-trade nexus does not come up with any result that is contrary to expectations of a positive relation (see appendix). Conversely, higher export revenues lead to higher public spending on education in some periods in the case of Brazil (see Musacchio et al. 2014), and Gelb (1988) reports that large shares of export revenues go to public investment in several resource-rich countries.

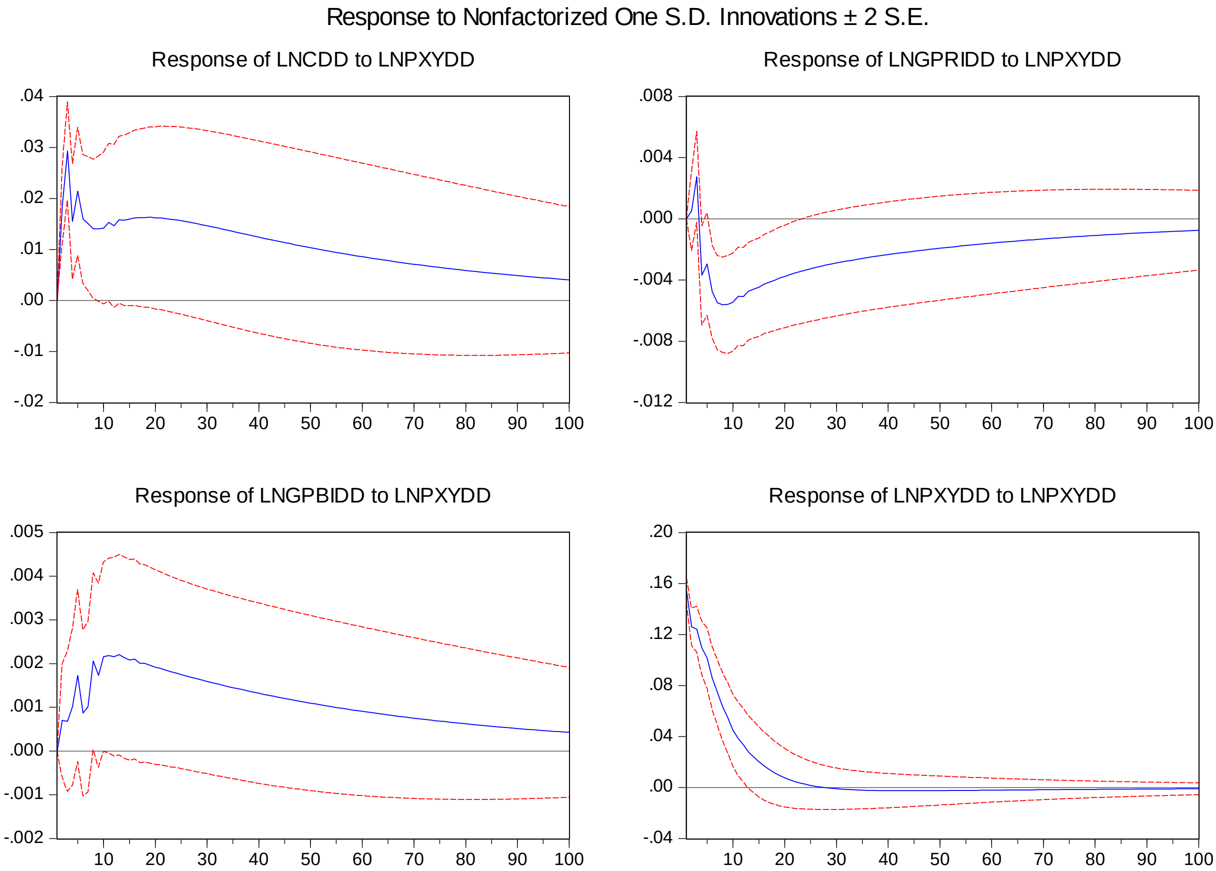

Figure 1: A transitory shock to the export share of 33 countries in Sub-Saharan Africa phases out only after 25 years, increases the share of public investment, first increases and then slightly reduces that of private investment, and increases consumption per capita.

Eden and Kraay (2014) emphasize that public and private investment may both be driven by third factors. As an illustration of the link between exports, public and private investment, we use panel data for thirty three Sub-Saharan African countries 1965-2011. We include consumption per capita, take the other variables as share of GDP,[6] demean the data using the standard procedure to include country and time fixed effects ((see Greene 2008, p.198), pool the data and estimate a vector-autoregressive model with five lags as suggested by the Akaike Information criterion and the Final Forecast Error. Then a temporary shock by one standard deviation on the share of export has the effects shown in Figure 1: exports deviate positively from the baseline for 25 years and then are slightly lower; public

[6] *Ln* stands for the natural logarithm, *gpri* for the share of private investment, *gpbi* for the share of public investment, *pxY* for the share of exports, *dd* for double demeaning by fixed country and period effects.

investment is replacing private investment at small amounts and consumption is strongly increased through higher exports and a better balance between private and public capital. If the shock is instead on public investment (not shown) the positive effect on private investment is larger and that on consumption and exports is smaller. This latter result is mainly due to falling terms of trade after the shock, as can be shown by extending the model to include the terms of trade. As the figure shows, exports may be a force that affects both, public and private investment, especially when other means of financing are scarce (Bertelsmann-Scott et al 2016). We would not see this as an argument against public investment but rather one that emphasizes that public investment, if not pushing the supply side, should at least follow exports and private investment rather than becoming a bottleneck. The classical export enclave argument, however, says that public investment does this in response to export shocks but not in response to private investment shocks. This can also be shown with our panel data. It indicates possibilities for improvement in public investment strategies in SSA.

Instead of a panel average, one can also look at countries with disproportionately low public capital. Garcia-Escribano et al. (2015) look at the infrastructure of Brazil in comparison with the major competitors of its top 10 export products and find that Brazil scores low in regard to roads, harbours, railroads, air ports, and electricity.

In sum, it seems worthwhile to set up a growth model where the crucial parameters of public capital and export demand function change all formulas for the transitional and long-run growth rates and levels through their connection by relative prices of domestic and foreign goods. In section 2, we generalize the Solow model in regard to those aspects which are essential in changing steady state growth rates as shown in the analysis of section 3 - with many simplifying assumptions when compared to multi-sector growth models. The variables emphasized in sections 2 and 3 are used in section 4 - for a country with good data availability, Trinidad and Tobago, - to show that the results from a vector-error-correction model coincide with those of the theoretical model after some minor country-specific adjustments. Section 5 summaries and concludes with some comparisons of the theoretical and empirical models with those of exogenous and (semi-) endogenous growth models.

2. The model

It is assumed that a country produces one good under constant returns to scale described by a Cobb-Douglas function. *Y* denotes output, *g* represents the growth rate of technology or total factor productivity and *K*, *H*, and L_1 stand for private physical capital, human capital and (unskilled) labour inputs, respectively. *A* is a level parameter. The production function is

$$Y = A_0 e^{gt} K^{\alpha} H^{\beta} {L_1}^{(1-\alpha-\beta)}, 0 < \alpha, \beta, \alpha + \beta < 1 \quad (1)$$

Adopting the notation of '^' for growth rates, (1) can be reformulated as:

$$\hat{Y} = g + \alpha\hat{K} + \beta\hat{H} + (1 - \alpha - \beta)\hat{L}_1 \quad (1')$$

Denoting the derivative of a variable with respect to time by a dot on the variable, net-investment in each period is denoted as $\dot{K}$. Ruling out international debt for the sake of simplicity, equality between investments and savings is given by

$$\dot{K} + \delta K = s\, p\, (1 - \kappa\tau)Y \tag{2}$$

Where s is a percentage rate of saving out of net income, p is the relative price of exported output to the price of imported capital inputs, and τ is a flat-rate income tax. In line with Pritchett (2000), we assume that from tax revenues τY, bureaucracy and corruption extract $(1\text{-}\kappa)\tau Y$, $\kappa \leq 1$. It is a partly illegal income of private households acting like a tax reduction if $\kappa < 1$. The sum of net factor income income, $(1\text{-}\tau)Y$, and legal and illegal income from transaction costs, $(1\text{-}\kappa)\tau Y$, is the term in (2). For the sake of simplicity we ignore the possibility of incurring debt and pay for imports later. This avoids complications, which are unnecessary for our purposes. Imported capital goods, ignoring other imports, have to be paid for by exports, where X measures exports in terms of domestic goods.

$$\dot{K} + \delta K = p\, X \tag{3}$$

As long as the share of imported capital goods in total imports is empirically approximately constant, this will not be a restrictive assumption. The equality of savings and exports that follows from assumptions (2) and (3) is typical of the two-gap models since Chenery and Bruno (1962) to Feder (1981), where the equations were called the savings gap and the export gap. Income and price elasticities of export demand are denoted by ρ and η, respectively and D is a level parameter. They all may differ by country, whereas in the multi-country model of Acemoglu and Ventura (2002) tractability requires that income and price elasticities are identical and therefore unity for income. World income (or the income of the country's customers) is denoted by Z. The export demand function is

$$X = DZ^{\rho}\, p^{\eta}, \eta < 0 \tag{4}$$

We assume that policy does not interfere trying to impose an optimal tariff because of the standard retaliation argument and trade agreements excluding this. To produce human capital, each individual with upper index $[i = 1, \ldots, N]$ can distribute her total labour endowment between selling unskilled labour, L_1^i, in the labour market or using labour inputs, L_2^i, for human capital (skilled labour) formation, so that an individual's labour constraint is given by

$$L^i = {L_1}^i + {L_2}^i \tag{5}$$

The L^i terms are individual labour endowments which cannot be observed by the government. To keep things as simple as possible the labour force, N, is identified as the total population. Assuming constant population growth at rate ε with e as the exponential function gives:

$$N = N(0)e^{\varepsilon t} \tag{6}$$

Equilibrium in the market for unskilled labour equates firms' demand with the sum of individuals' supply:

$$L_1 = \sum_{1}^{N} L_1^i \quad (7)$$

Human capital is formed by each individual using labour inputs L_2^i, exogenous individually different labour-augmenting (learning) abilities e^i, and a public factor B, which can be understood either as basic research results financed by the government, a domestic knowledge stock or other public physical and institutional capital for provision of water, transport services, electricity and communication, which interact with health and education (see Leipziger et al. 2003, Stone et al. 2010; Calderón and Servén 2014a). As with the individual labour endowments, the government cannot observe individual learning abilities. Human capital is assumed to depreciate completely after each period, since it cannot be transmitted between generations. Total depreciation simplifies the model considerably. The human-capital production function with constant level parameter F is assumed to be[7]

$$H^i = F(e^i\, {L_2}^i)^{\varphi}\, B^{(1-\varphi)}, 0 < \varphi < 1 \quad (8)$$

Alternatively, one could interpret H^i as transport or telecommunication service and B as transport or communication infrastructure, both with heterogeneous productivities e^i. The change in the stock of public factors is financed by the government through a flat-rate tax τ, diminished by a factor $\kappa < 1$ capturing bureaucracy and corruption costs as suggested and modelled by Pritchett (2000), Agénor (2010), Dabla-Norris et al. (2012) and Gupta et al. (2014). The public capital stock is assumed to depreciate at a rate θ:

$$\dot{B} = \kappa\tau Y - \theta B \quad (9)$$

By implication, B is efficiency-adjusted capital and $\kappa\tau Y$ is the efficiency adjusted gross investment. Bureaucracy and corruption are treated here and in (3) as a reduction of tax revenue and payments, because it is not lost but rather goes from public into private budgets, whereas in other literature it is treated as a pure waste, or remains in the firms' budgets (Berg et al. 2013).[8] Equilibrium in the market for human capital equates firms' demand with the sum of individuals' supply

$$H = \sum_{1}^{N} H^i \quad (10)$$

[7] Among the earlier growth models with human capital production functions using public capital as inputs are Ziesemer (1990, 1991, 1995), Agénor (2010), Agénor and Néanidis (2015). Agénor (2012) shows that a decreasing marginal product of labour in human capital formation can be based on a moderate quality effect of congestion captured by the pupil/teacher ratio.

[8] See Berg et al. (2015) for a broader discussion. In most variants they discuss the $\kappa < 1$ drives money to other persons, but does not evaporate, because administrators, bureaucrats etc. are all part of the household sector.

Profit maximization by firms results in the following marginal productivity conditions (with *r* denoting interest on capital, δ the rate of capital depreciation, *q* the market price of human capital, and *w* the wage rate for unskilled labour):

$$r + \delta = \alpha \frac{pY}{K} \tag{11.1}$$

$$q = \beta \frac{Y}{H} \tag{11.2}$$

$$w = (1 - \alpha - \beta)\frac{Y}{L_1} \tag{11.3}$$

The Bardhan and Lewis (1970) model and that of Acemoglu and Ventura (2002) have in common that the terms of trade appear in the formula for the marginal product of capital as they do in equation (11.1).

Individuals maximize their income by deciding on the optimal allocation of their individual labour endowments over unskilled labour L_1^i and labour spend in human capital formation L_2^i,[9] which requires that the value of the marginal product of labour in human capital formation equals the real wage rate in terms of human capital prices

$$\frac{w}{q} = \varphi \frac{H^i}{{L_2}^i} \tag{12}$$

Since all individuals face the same real wage rate, *w*, and rental price for human capital, *q,* and abilities are labour-augmenting by assumption*,* it follows from (12) that the human capital – labour ratio is identical for all individuals and therefore equal to the aggregate relation.

$$\frac{H}{L_2} = \frac{H^i}{{L_2}^i} \tag{13}$$

This property of the model avoids having complicated aggregation problems in our case of heterogeneous households. However, labour-augmenting differences in abilities e^i in (8) imply that people with higher abilities spend more hours in education, ${L_2}^i$, and produce more human capital, H^i, although their ratio remains the same. This can be seen from Figure 2, which plots equation (8) after division by *B* as $H^i/B = F(e^i\, {L_2}^i/B)^{\varphi}$ for two different levels of e^i. Then, according to (12) and (13), the tangents with slope *w/q* lead to the same human capital/labour ratio, which is the slope of the line from the origin through the two tangential points. According to Euler's theorem the intercept of the two tangential lines are the marginal products of *B* in H^i. Multiplied by the price *q* this expresses the

[9] Households decide how to distribute individual labour endowments by maximising

$$\max(1-\tau)\left[q\, H^i + w{L_1}^i\right]\ s.t.(5)\ and\ (8).$$

Insertion of (5) and (8) yields

$$(1-\tau)\left[q\, F(e^i\, {L_2}^i)^{\varphi}\, B^{(1-\varphi)} + w\left(L^i - {L_2}^i\right)\right]$$

Maximization with respect to L_2^i gives (12).

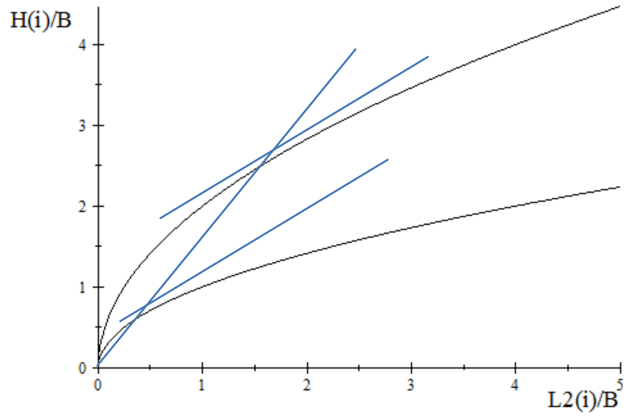

Figure 2 Households with higher abilities invest more time in education and form more human capital.

Lindahl tax, $l^i = q\partial H^i/\partial B = (1-\varphi)F(e^i L_2{}^i)^{\varphi} B^{\varphi} = q(1-\varphi)H^i/B$, which differs for the individuals and would be the ideal tax rate per individual because it is efficient and implies no re-distributional conflicts. However, Lindahl taxes are not feasible since the government would need to know the individual production functions, in particular the abilities e^i. Flat rate income taxes are chosen in this model as the simplest alternative. Taking into account the consequences for the level of public capital, individuals with a higher marginal benefit from public capital would prefer a higher flat rate income tax then people with a lower marginal benefit of B. We express individuals gross income as $Y^i = rK^i + qH^i + wL^i$. Using (11.2), we compare the Lindahl tax bill $l^iB = (\beta Y/H)(1-\varphi)H^i$ to the effective flat rate tax bill $\kappa t Y^i$. Dividing both expressions by H^i we compare $(1-\varphi)\beta Y/H$ and $\kappa t Y^i/H^i$. Assuming $\kappa t = (1-\varphi)\beta$,[10] a golden rule when not exploiting terms of trade effects, tax terms can be cancelled from the previous terms and given the macro value of Y/H, a person with $Y/H < (>)\ Y^i / H^i = rK^i/H^i + q + wL^i/H^i$ will pay less (more) under the Lindahl tax than under a golden rule if (s)he has a higher capital or labour endowment or less human capital. Therefore (s)he will resist the golden rule, because the non-redistributive Lindahl tax bill, indicating the willingness to pay, is lower. The vested interests of people using public capital intensively are different from those owning capital and labour above average, all measured relative to their human capital. Agreement is hard to achieve and resistance against taxation or public investment has been strong in many countries.[11] Whereas the macroeconomic data for investment and savings as a share of GDP of the least developed countries are higher than those of the USA since 2002, and were close to them since many decennia, this is not the case in regard to public goods and networks related to water, waste water, transport (roads, railroads,

[10] The golden rule tax τ is higher the lower κ. The inefficiency measure $1\text{-}\kappa$ has a redistribution effect if it goes to only some people whereas others have to pay higher taxes to stick the constant product $\kappa\tau$. In the above reasoning we assume symmetry. Asymmetry makes the argument more complicated but it would hold in spirit.

[11] For a recent article regarding regulation as a means to slow down public investment and capital in Brazil see Amann et al. (2016). It seems to be an open issue at this moment whether revenues from resource windfalls can be channelled more easily into public investment than tax money in many countries as it could in Trinidad and Tobago (Gelb 1988, Berg et al. 2013).

harbours, airports), electricity, education, health, and internet, all of which affect human capital.[12] Although the literature has achieved consensus to keep distortions low, the redistributive character of other than Lindahl taxes and for public investment has remained controversial. Similarly, in the examples for transport and telecommunication, productivity differences of transport and ICT firms replace abilities or different productivities of human capital producing households. This type of tax conflicts can only be solved by policy, and in order not to narrow down the model to certain policy constellations we leave the tax exogenous.[13]

Daido and Tabata (2013) show that countries may catch up even if public and private investment follow each other sequentially if production of public investment is sufficiently high. They model an egalitarian society with individuals identical up to different expectations regarding public investment and a government that weighs all incomes identical in the welfare function. This is an adequate modelling for the purpose of showing what is possible provided that the choice of a high-productivity technology is available as assumed. Less favourable conditions may lead to a low-level equilibrium trap in their model and will have level effects in our semi-endogenous growth model. In Hosoya (2016), besides a low-level equilibrium trap, there is also indeterminacy allowing for favourable development under optimistic expectations if the public capital in the production function also appears in the utility function with a sufficiently high elasticity of utility. Both of these papers are modelling interesting but also highly special constellations for public capital with an enormous leverage regarding effect of either technologies or expectations. In our model, the possibly strong endogenous impact comes from a combination of world income growth, possibly high income elasticities and adequate investment in public factors.

A standard argument against our pure public good model is that there are congestion effects which justify raising fees (see Calderón and Servén 2014b for brief and clear survey). However, raising fees requires fixed costs from investments in measurement and payment technologies and may increase the congestion during the payment. Therefore in congested areas of French highways there are no fees in order not to increase congestion. Fees are raised only in case of the presence of a less luxury alternative. In the Netherlands there is congestion on all highways and therefore no government has ever implemented fees even if the parties in the government have advocated it before the elections; here the less luxury alternative would be the train, which is already overcrowded and experiences limits to further investment. In short, in the presence of fees, modelling of technologies needs to be adjusted to include fixed costs and congestion effects of payment technologies. In several articles the question of the purity of the public good leads to actual modelling of publicly provided private goods and clear-cut rules of optimum taxation. The question whether there is some element of public goods modelled as we do here, leads to a role for governments which may bring in tax resistance leading to

[12] See World Development Reports 1990, 1991, 1994 for early contributions, Shepherd et al (2014), Eden and Kraay (2014), World Development Report 2016 for recent ones.

[13] See Haldenwang and Schiller (2016) for literature on political and other factors determining taxation and spending.

the underprovision of semi-public infrastructure in developing countries because a clear concept of optimality like Lindahl taxes is not feasible and distributional conflicts prevail according to the model. The result is underprovision of public capital in most poor countries (Eden and Kraay 2014), but policy can change this low level into a higher one.

Equating the right hand side of (12) with the quotient of the marginal productivity conditions (11.2) and (11.3), both of which represent the impact of wages on the demand for labour, and making use of (13) implies:

$$\frac{L_1}{L_2} = \frac{(1-\alpha-\beta)}{\beta\,\varphi} \tag{14}$$

The allocation of total labour endowments over the formation of human capital, L_2, and unskilled labour, L_1, according to (14) is determined by their respective production elasticities in regards to the final output. Insertion of *H* from (13) and H^i from (8) into (1) yields the production function in the form that includes public capital *B* instead of human capital:

$$Y = A_0 e^{gt} B^{(1-\varphi)\beta} K^{\alpha} \left[\frac{F(e^i L_2{}^i)^{\varphi}}{L_2{}^i} L_2\right]^{\beta} L_1{}^{(1-\alpha-\beta)} \tag{1''}$$

It will be shown below that the fraction in (1'') is constant over time as the individual labour terms are constant. This function has increasing returns to scale because the sum of exponents of *B, K,* L_1 and L_2. The macroeconomic labour terms and capital *K* have constant returns. The productivity of the constant-returns function can then be split up into a public capital term and a total factor productivity term. The intensive form as in Chakraborty and Lahiri (2007) is then

$$\frac{Y}{L_1} = A_0 e^{gt} B^{(1-\varphi)\beta} \left(\frac{K}{L_1}\right)^{\alpha} \left[\frac{F(e^i L_2{}^i)^{\varphi}}{L_2{}^i}\frac{L_2}{L_1}\right]^{\beta} = (Ae^{gt})^{\frac{1}{1-\alpha}} B^{\frac{(1-\varphi)\beta}{1-\alpha}} \left(\frac{\frac{K}{L_1}}{\frac{Y}{L_1}}\right)^{\frac{\alpha}{1-\alpha}} \left[\frac{F(e^i L_2{}^i)^{\varphi}}{L_2{}^i}\frac{L_2}{L_1}\right]^{\frac{\beta}{1-\alpha}}$$

Output per worker can be attributed to TFP, public capital, the capital/output ratio and the share of education time, which corresponds to the education arguments in the growth accounting literature. As emphasized by Acemoglu and Ventura (2002), postulating a high value of $\alpha = 2/3$ or $\alpha/(1-\alpha) = 2$ leads to a strong role of capital and a weak one for total factor productivity because *A* has exponent three leading to a lower value of *A* to explain the left-hand side values than with a lower exponent. In Chakraborty and Lahiri (2007) the same mechanism is used to postulate a strong role of public capital. But the standard value of $\alpha = 1/3$ yields $\alpha/(1-\alpha) = ½$ and an exponent for *A* of *3/2*, requiring a higher value of *A* to explain the left-hand side values than with a higher exponent. A strong role for public capital *B* in this case requires high $(1-\varphi)\beta$, a high elasticity of production of *H* in (1) and of *B* in (8). We will use these equations below to calculate the total factor productivity growth rate *g*.

3. Equilibrium dynamics

From the allocation of labour in (14) it follows that the two kinds of labour grow at identical rates.

$$\hat{L}_1 = \hat{L}_2 \quad (14')$$

Assuming that the population reproduces at a constant average labour endowment $\bar{L}^i$, (5) and (6) imply

$$L_1 + L_2 = N\bar{L}^i \quad (5')$$

From (14'), (5') and (6), we find

$$\hat{L}_1 = \hat{L}_2 = \varepsilon \quad (14'')$$

Aggregated labour services in both purposes grow at the rate of population growth. Expressing (12), (13) and (8) in growth rates and using (14'') yields

$$\hat{H} - \varepsilon = \hat{H}^i - \hat{L}_2{}^i = (1-\varphi)(\hat{B} - \hat{L}_2{}^i) = \hat{w} - \hat{q} \quad (13')$$

The first equation is (13) in growth rates, the second from (8) and the third from (12). Since all variables in (13'), perhaps besides the $\hat{L}_2{}^i$, are equal for all individuals, the $\hat{L}_2{}^i$ must also be equal for all individuals. And because of (14'') we get

$$\hat{L}_1{}^i = \hat{L}_2{}^i = 0 \quad (15)$$

To compute steady-state growth rates for human capital, inserting (15) into the left hand sides of (13') yields

$$\hat{H} = (1-\varphi)\hat{B} + \varepsilon \quad (8')$$

Human capital per capita grows at a rate proportional to the stock of the public factor. Inserting (8') into (1') we get

$$\hat{Y} = g + \alpha\hat{K} + \beta(1-\varphi)\hat{B} + (1-\alpha)\varepsilon \quad (1''')$$

Dividing (9) by *B* and rewriting in growth rates using (1''') we obtain

$$dlog\left(\hat{B} + \theta\right) = \ln A + g + \alpha\hat{K} + [\beta(1-\varphi) - 1]\hat{B} + (1-\alpha)\varepsilon \quad (9')$$

Dividing (3) by *K*, taking the growth rates to solve for $\hat{p}$, we get

$$\hat{p} = \frac{dlog(\hat{K} + \delta) + \hat{K} - \rho\hat{Z}}{(1+\eta)} \quad (16)$$

Equations (16) and (2) indicate that there is two-way causality between capital accumulation on the one hand and the terms of trade and exports on the other.[14] Dividing (2) by *K*, and taking log differences, using (1''') and (16) we get

$$dlog\left(\hat{K} + \delta\right) = -\frac{\eta(1-\alpha) - \alpha}{\eta}\hat{K} - \frac{\rho\hat{Z}}{\eta} + \frac{(1+\eta)}{\eta}[g + (1-\alpha)\varepsilon + \beta(1-\varphi)\hat{B}] \quad (17)$$

[14] Se Sakyi et al. (2014) for panel evidence.

World income growth multiplied by the income elasticity - ignoring the theoretical possibility of a negative income elasticity from the discussion as it has never been mentioned in the development literature for the country level - will drive up the terms of trade in (16) in case of price elastic exports and through that also capital accumulation as in all models based on Bardhan and Lewis (1970). Falling capital goods prices, which serve as numéraire here, or increasing terms of trade, are the mirror image of the process of stimulating capital accumulation in (17) as discussed by Cai et al. (2015). On the other hand, (16) indicates that this effect is mitigated by the negative impact of capital accumulation on the terms of trade – emphasized by Acemoglu and Ventura (2002) - in case of a price elasticity making the denominator of (16) negative. The more negative the price elasticity the weaker the effects of the right-hand variables on the terms of trade growth in (16) and the weaker the effects on capital accumulation in (17).

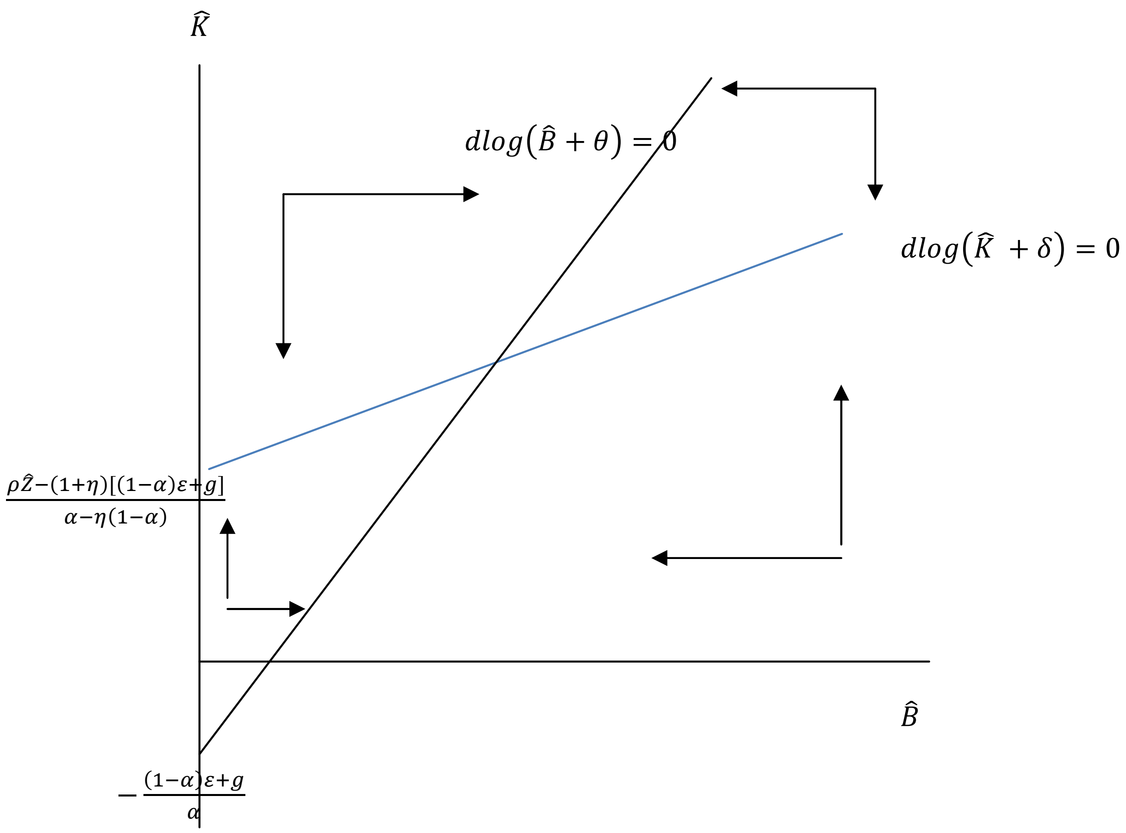

Figure 3. Existence, uniqueness and stability of a steady state if export demand is price elastic.

3.1 Existence, uniqueness and stability of the steady state

The differential equations (9') and (17) can be most easily considered in a $(\hat{K},\hat{B})$-plane. The $dlog(\hat{K}+\delta)=0, dlog(\hat{B}+\theta)=0$ lines are:

$$\widehat{K} = -\frac{[g + (1-\alpha)\varepsilon]}{\alpha} + \frac{1-\beta(1-\varphi)}{\alpha}\widehat{B} \qquad (9'')$$

and

$$\widehat{K} = \frac{\rho\hat{Z} - (1+\eta)[g + (1-\alpha)\varepsilon]}{\alpha - \eta(1-\alpha)} - \frac{\beta(1-\varphi)(1+\eta)}{\alpha - \eta(1-\alpha)}\widehat{B} \qquad (17')$$

Equations (9'') and (17') are drawn in Figure 3. (9'') has a positive slope and a negative intercept. For (17') the denominators of both fractions are positive; the slope is positive in the price elastic case, but negative in the inelastic case. In the price elastic case, the intercept is positive, whereas in the price inelastic case it can be negative. The price elastic case $(1+\eta < 0)$ can be analysed as follows. Existence of a steady state requires that (9'') has a steeper slope than (17'). This in turn requires that $\eta\big(1-\alpha-\beta(1-\varphi)\big) < \alpha$. As the left-hand side is negative and the right-hand side is positive this is fulfilled without any further assumptions. Routine thoughts about adjustments taking place off the stationary lines are drawn as arrows in Figure 3 and indicate stability.

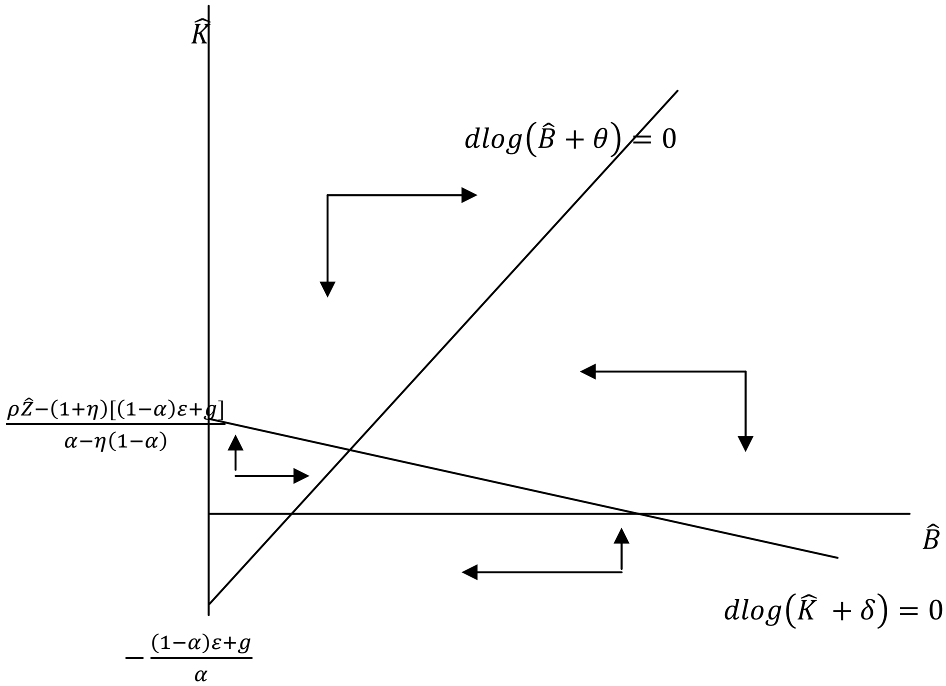

Figure 4. Existence, uniqueness and stability of a steady state if export demand is price inelastic.

The price inelastic case $(1+\eta > 0)$ can be analysed as follows. (17') has a negative slope now. Therefore it must have a higher intercept than (9''). This is the case if $\alpha\rho\hat{Z} > \eta[g + (1-\alpha)\varepsilon]$. As the left-hand side is positive and the right-hand side negative this is fulfilled without further assumptions. The case is drawn in Figure 4, where the higher intercept could be negative as well. In that case a negative steady-state growth rate of capital would be possible meaning that depreciation is larger than gross investment. It follows already from (2), (3) and (9) that in a steady state the growth rates are the same for *Y, B, K/p*, and *X*. A steady state with a negative growth rate of *K* would then imply a negative growth rate of p as well, which implies that machines are becoming increasingly expensive and therefore are accumulated less and less. Routine analysis for dynamics off the stationary lines yields arrows as drawn. They indicate again stability.

3.2 Terms of trade dynamics outside the steady state

To solve for the growth rate of the terms of trade, which is valid also outside the steady state, we use (17) in (16). Rearranging terms results in

$$\hat{p} = \frac{1}{-\eta}[\rho\hat{Z} - (\alpha\hat{K} + g + (1-\alpha)\varepsilon + \beta(1-\varphi)\hat{B})] \tag{18}$$

The first term in brackets is the growth rate of export demand at constant terms of trade and the second term in parentheses is the growth rate of domestic supply, private and public capital, technical change and labour supply. Public capital as well as the other supply factors' growth decreases the growth rate of the terms of trade, and in case of a sufficiently high price elasticity this increases the growth of export values. World income growth increases the growth rate of the terms of trade.

3.3 Steady-state growth rates

To solve for $\hat{B}$, equate (9'') and (17') to get

$$\hat{B} = \frac{\alpha\rho\hat{Z} - \eta[g + (1-\alpha)\varepsilon]}{\alpha - \eta(1-\alpha-\beta(1-\varphi))} \tag{19}$$

The denominator is positive for all values of non-positive price elasticities. The first term in the numerator has the following interpretation. Higher world income growth and a higher income elasticity of export demand (depending on the underlying composition)[15] increase the growth rate of output and therefore also the growth rate of tax revenues and public capital, which goes into education according to the model as described by Musacchio et al. (2014) for some historical periods of Brazil. The second term has the following interpretation. Technical change and the growth of the population with access to the non-rivalrous public factors increase the supply of goods, reduce prices, increase exports, imported capital goods and output growth, and therefore the growth of public capital. World income growth effects are smaller for a more negative price elasticity. Letting price elasticities go to minus infinity after dividing numerator and denominator by η, the limiting case where the demand curve is horizontal in p-X plane, yields a small country growth rate of

$$\lim\ \hat{B}_{-\eta\to\infty} = \frac{[g + (1-\alpha)\varepsilon]}{(1-\alpha-\beta(1-\varphi))} \tag{19'}$$

[15] See Greenaway et al. (1999), Aditya and Acharyya (2013), Ramanyake and Lee (2015).

This rate is larger than ε, because it is the growth stemming from repeated costless use of the non-rivalrous public factor. As in other semi-endogenous growth models such as Arrow (1962) and Jones (1995) it is therefore proportional to the population growth in the sense of having additional costless users of externalities. Imported capital goods and the parameters of the export demand function as well as technical change *g* change the growth rate of public capital in (19) considerably. Export demand elasticities are only irrelevant for the small country case. Inserting (19) back into (9'') gives the expression for $\widehat{K}$

$$\widehat{K} = \frac{\left(1-\beta(1-\varphi)\right)\rho\hat{Z} - (1+\eta)[g+(1-\alpha)\varepsilon]}{\alpha - \eta\left(1-\alpha-\beta(1-\varphi)\right)} \tag{20}$$

The interpretation of (20) is as follows. A higher world income growth and a higher income elasticity of export demand allow for more imported capital goods, which are diminished by the extent to which higher output yields more public factors in the production and use of human capital. Technical change and the rate of population growth analogous to (18) reduce unit costs and cost prices. To the extent that export demand is elastic, $(1+\eta) < 0$, the value of exports will be higher and so will the capital goods imports, leading to higher growth rates. Dividing numerator and denominator of (20) by the price elasticity $-\eta$ and letting it go to infinity would yield

$$\lim\ \widehat{K}_{-\eta\to\infty} = \frac{[g+(1-\alpha)\varepsilon]}{\left(1-\alpha-\beta(1-\varphi)\right)} \tag{20'}$$

Again, the growth rate for the small open economy is as large as that of the closed economy and independent of parameters of the export function.

To solve for the steady-state growth rate of the terms of trade use (19), (20) in (18)

$$\hat{p} = \frac{\left(1-\alpha-\beta(1-\varphi)\right)(\rho\hat{Z}-\varepsilon) - [g+\beta(1-\varphi)\varepsilon]}{\alpha - \eta\left(1-\alpha-\beta(1-\varphi)\right)} \tag{21}$$

The first term in the numerator can be interpreted as the growth rate of export demand per capita at constant terms of trade and the second term as the growth rate of per capita supply at constant terms of trade. The terms of trade will be constant in the long run only in the special case that these two growth rates are identical, provided the price elasticity is not minus infinity. Higher world income growth and income elasticities of export demand drive the terms of trade growth up and technical change, either exogenous or from the usage of the non-rivalrous public factor, drive them down because they reduce unit costs. The terms of trade growth rate reacts more strongly to all changes the less price-elastic export demand is. Moreover, (21) is the difference between (20) and (19), the growth rates of imported foreign and domestic public capital, because we have an elasticity of substitution of unity. Division of the numerator and denominator by the price elasticity and letting it go to infinity again would yield a terms of trade growth rate of zero, because in the small country case the terms of trade are given and constant at the relative unit costs of domestic and foreign goods. To solve for the growth rate of human capital accumulation insert (19) into (8')

$$\hat{H} = \frac{\alpha(1-\varphi)\rho\hat{Z} - \eta(1-\varphi)g + \left(\alpha - \eta\left(1-\alpha+(1-\alpha-\beta)(1-\varphi)\right)\right)\varepsilon}{\alpha - \eta\left(1-\alpha-\beta(1-\varphi)\right)} \tag{22}$$

Higher world income growth and income elasticities of export demand lead to more exports, imported capital goods, investment, output and public capital and therefore to more human capital, all in terms of growth rates. Similarly, a larger rate of technical change reduces costs and prices more quickly and therefore also leads to more exports, imported capital goods, investment, output and public capital and therefore to more human capital. Therefore these effects are larger under a more price elastic export demand. To solve for output growth insert (19) and (20) into (1''')

$$\hat{Y} = \frac{\alpha\rho\hat{Z} - \eta[g + (1-\alpha)\varepsilon]}{\alpha - \eta\left(1-\alpha-\beta(1-\varphi)\right)} \tag{23}$$

The mechanisms are the same as for all the other solutions.[16] If the price elasticity were zero the growth rate in (23) would be just $\rho\hat{Z}$; if the price elasticity were *-1*, we would have

$$\hat{Y}_{\eta=-1} = \frac{\alpha\rho\hat{Z} + [g + (1-\alpha)\varepsilon]}{\left(1-\beta(1-\varphi)\right)}$$

This version of the growth rate has the three driving forces in its purest form: exogenous technical change, g, use of externalities, and world income growth multiplied by the income elasticity of export demand and the elasticity of production of capital that can be imported by use of export revenues. With price elasticity of minus infinity we would have the closed and small economy growth rate for output per capita of labour augmenting technical change plus that of non-rivalrous use of public goods.

$$\left(\hat{Y} - \varepsilon\right)_{\eta\to-\infty} = \frac{g + (1-\alpha)\varepsilon}{\left(1-\alpha-\beta(1-\varphi)\right)} - \varepsilon = \frac{g + \beta(1-\varphi)\varepsilon}{\left(1-\alpha-\beta(1-\varphi)\right)} \tag{23'}$$

In (19)-(23) the impact of the income elasticity of export demand is larger the less price elastic export demand is.

To solve for the growth rates of *q* and *w*, where the latter is equal to the growth rate of GDP per capita, take the growth rate of (11.2) and (11.3) and use (23), (22) and (14''), respectively.

[16] A related business cycle literature looks at the correlation of the standard deviations of the growth rates of GDP per capita and terms of trade, assuming that the latter are exogenous (Alimi and Aflouk 2017). Our equations (21) and (23) would suggest that the terms of trade growth and its standard deviation are both endogenous and that growth rates of world income, population and technical change should be used as regressors too. World income growth would work in the direction of a positive correlation between the standard deviations whereas technical change and population growth would work towards a negative correlation. As poor countries may have no technical change a positive correlation often found in the literature becomes more likely for them.

$$\hat{q} = \frac{\alpha\varphi\rho\hat{Z} - \eta\varphi g - \big(\alpha - \eta(1-\alpha-\beta)(1-\varphi)\big)\varepsilon}{\alpha - \eta\big(1-\alpha-\beta(1-\varphi)\big)} \tag{24}$$

$$\hat{w} = \frac{\alpha(\rho\hat{Z} - \varepsilon) - \eta g - \eta\beta(1-\varphi)\varepsilon}{\alpha - \eta\big(1-\alpha-\beta(1-\varphi)\big)} = \hat{Y} - \varepsilon \tag{25}$$

The interpretation of wages is analogous to that of output in (23). Population growth, through its effect on non-rivalrous use of public factors, human capital, and output has the same effects as exogenous technical change. For (24) all arguments appear in the supply of human capital via public factors as well as in the export demand via capital imports and output. The major aspect here is the effect of the parameter of the human capital production function. A higher φ is a lower elasticity of production of public capital, and implies – other things equal - a lower supply of human capital and therefore a lower fall of human capital prices when public capital grows with output in the first two terms of the numerator of (24). The $(1-\varphi)$ term at the end captures the non-rivalry aspects, which enhances the human capital growth rate and therefore has a negative effect in (24). Moreover, equations (24) and (25) add a dynamic effect of capital imports on relative wages, which complements the idea of skill-enhanced static Heckscher-Ohlin theory (see Posso and Soans 2014). Whereas in the latter capital goods imports may increase wage inequality, in (24) and (25) capital goods imports are represented by the export terms paying for them: world income growth multiplied by the income elasticity of export demand and the elasticity of production of physical capital. In (25) there is also a multiplication by the elasticity of production of labour in human capital formation. As this latter elasticity is below unity the dynamic effect of capital imports works in favour of relative low-skilled wages, which is the opposite of the suggestion of the static skill-enhanced theory. The dynamic effect working against the static one therefore adds some plausibility to the insignificant effect found by Posso and Soans (2014).

Define $k \equiv \frac{K}{L_1}$ as the capital-labour ratio and $h \equiv \frac{H}{L_1}$ as the human capital labour ratio, so that the ratios' growth rates are given by

$$\hat{k} = \hat{K} - \widehat{L_1} \tag{26}$$

and

$$\hat{h} = \hat{H} - \widehat{L_1} \tag{27}$$

Inserting (20) and (14'') into (26), and (22) and (14'') into (27), respectively, gives the growth rate of the capital-labour and human capital-labour ratios

$$\hat{k} = \frac{\big(1-\beta(1-\varphi)\big)\rho\hat{Z} - \big(1+\eta\beta(1-\varphi)\big)\varepsilon - (1+\eta)g}{\alpha - \eta\big(1-\alpha-\beta(1-\varphi)\big)} \tag{26'}$$

$$\hat{h} = \frac{\alpha(1-\varphi)\rho\hat{Z} - \eta(1-\alpha)(1-\varphi)\varepsilon - \eta(1-\varphi)g}{\alpha - \eta\big(1-\alpha-\beta(1-\varphi)\big)} \tag{27'}$$

In (26') most terms have the same interpretation as before. $\beta(1-\varphi)$ has opposite effects. World income growth although translated into physical capital, has an effect that is lower the higher the elasticity of production of public capital is in human capital formation and from there in output production. On the other hand, as in (23') and (25), $\beta(1-\varphi)\varepsilon$ is the per capita total factor productivity growth rate of the economy from externalities of the public factor in the absence of trade and exogenous technical change. It works like technical change making goods cheaper, decreasing prices and allowing for more exports the more price elastic exports are. In (27') all three terms of the numerator are enhanced by $(1-\varphi)$, the elasticity of production of public factors in human capital production, because all three terms enhance output growth, public capital growth and therefore human capital growth.

Income and price elasticities of export demand will differ from country to country and therefore none of the growth rates of this section will in general be identical across countries. The literature on total factor productivity accounting would suggest that exogenous growth rates g would also differ across countries (Perkins et al. 2013). Bernard and Jones (1996) doubt that elasticities of production are the same for each country. If only one of these ideas is true, growth rates differ between countries in the steady state. Pedroni (2007) provides evidence for the heterogeneity of elasticities of production and time trends in growth regressions. A constant distribution of growth rates (Easterly et al. 1993, Acemoglu and Ventura 2002) is still possible from the perspective of our model; even under structural change, if some economies shift to sectors with higher income elasticities others must shift to sectors with lower ones, which may keep the distribution constant. Structural change between sectors is most likely to change also factor productivity growth as captured by the coefficients of time trends. As world income growth appears in all formulas for steady state growth, it is a similar but broader idea than worldwide technical change emphasized by Easterly et al (1993); generally speaking, worldwide technical change, together with other factors, has an impact on world income growth, which in turn has an impact on the terms of trade in our equations (18) and (21); terms of trade effects are also emphasized by these authors and by Esfahani and Ramirez (2003) and they may partly come from world income growth as in our model.

4. The level of growth: Theory, policy and empirics

4.1 Transitional dynamics of variables in levels

To estimate our model in levels we first drop the constant returns to scale assumption with γ as elasticity of production for labour in (1) and re-write the model with stochastic terms in the production and export functions, giving first-order conditions above the status of expected values under risk neutrality. The equations for estimation are derived as follows. The production function is

$$Y = AUe^{gt}K^{\alpha}H^{\beta}{L_1}^{\gamma} \qquad (1^{iv})$$

The export demand function is then

$$X = DVZ^{\rho}\, p^{\eta} \tag{4'}$$

The stochastic term *U* makes output and growth stochastic and the term *V* is applied to either the export function or world income growth, which may take the form $e^{v}Z^{\rho} = Z(0)e^{v+\rho\omega t}$. Taking logs of (8) and (13) and inserting the former into the latter yields[17]

$$\ln H - (1-\varphi)\ln B - \ln L_2 - \ln F = \varphi \ln\left(e^{i}\, {L_2}^{i}\right) - \ln {L_2}^{i} \tag{13''}$$

Since all the terms on the left hand side of (13'') are the same for all individuals, it follows that the right hand side must be the same for all individuals. People with higher abilities e^{i} will spend more time in education, ${L_2}^{i}$. Replacing the latter by its average $L_2\,/\,N$ and the former with a constant average ability level $\bar{e}$ and defining the constant parts as $\lambda\ \equiv \ln F + \varphi \ln \bar{e}$ we get[18]

$$\ln H = (1-\varphi)\ln B + (1-\varphi)\ln N + \varphi \ln L_2 + \lambda \tag{13'''}$$

Dividing both sides of (9) by B, subtracting depreciation on both sides, taking logarithms, and using (1''') in logarithms and (13''') gives

$$\begin{aligned}\ln\left(\frac{\dot{B}}{B}+\theta\right) &= \ln A + \beta\lambda + \mathrm{g}t + \ln(\kappa\tau) + \gamma \ln L_1 - \beta\varphi \ln L_2 \\ &+(1-\varphi)\beta \ln N - (1-(1-\varphi)\beta)\ln B + \alpha \ln K + lnU\end{aligned} \tag{9'''}$$

Next, we divide (2) and (3) by *K*, take the depreciation rate to the left, and take the natural logarithms. In the former, we insert the log-version of the production function (1^{iv}) and (13'''), and in the latter we insert the log-version of the export function (4'). This yields the following two equations:

$$\begin{aligned}\ln\left(\frac{\dot{K}}{K}+\delta\right) &= \ln A + \beta\lambda + \mathrm{g}t + \ln s + \ln\ (1-\kappa\tau) + \gamma \ln L_1 - \beta\varphi \ln L_2 \\ &+ (1-\varphi)\beta \ln N + (1-\varphi)\beta \ln B - (1-\alpha)\ln K + \ln p + lnU\end{aligned} \tag{2'}$$

$$\ln\left(\frac{\dot{K}}{K}+\delta\right) = \ln D + \rho \ln Z - \ln K + (1+\eta)\ln p + lnV \tag{3'}$$

Next, equate (2') and (3') to solve for $\ln p$

$$\begin{aligned}\ln p = \frac{1}{\eta}(&\ln A - \ln D + \beta\lambda + \mathrm{g}t - \rho \ln Z + \ln s + \ln\ (1-\kappa\tau) + \gamma \ln L_1 \\ &- \beta\varphi \ln L_2 + (1-\varphi)\beta \ln N + (1-\varphi)\beta \ln B + \alpha \ln K) + (lnU \\ &- lnV)/\eta\end{aligned} \tag{18'}$$

[17] We ignore uncertainty in the education process, because the learning about one's own ability is a process as lengthy as the schooling process and beyond. Costly IQ test are only a very imperfect substitutes with unknown distribution of revealing the correct IQ. Stochastic processes trying to deal with this learning process are probably very complicated.

[18] Deviations from $\bar{e}$ could be employed as fixed effects in case of empirical work with household panel data.

The supply side arguments, including capital accumulation emphasized by Acemoglu and Ventura (2002) and technical change emphasized by Kravis (1970), reduce the terms of trade and the demand side arguments, like world income growth emphasized by Singer (1999), increase the terms of trade. These effects are stronger if the price elasticity is less negative. A higher efficiency parameter κ leads to higher public and lower private investment as well as consumption and exports, other things given; in this sense κ<1 is a distortion through a dynamic misallocation in line with the discussion in Berg et al. (2015). The effect is transitional only, because it is does not show up in the formulas for the steady-state growth rates above. The government efficiency parameter κ is positively related to the terms of trade. Therefore, a lower efficiency leads to lower terms of trade because exports supply is enhanced when less output is used for public investment. Insertion of $\ln p$ from the left-hand side of (18') into (2') or (3') yields (17'') below.

$$\ln\left(\frac{\dot{K}}{K}+\delta\right) = -\frac{1}{\eta}[\ln D + \rho \ln Z] + \frac{(1+\eta)}{\eta}(\ln A + \beta\lambda + gt + \ln s + \ln\ (1-\kappa\tau) + \gamma \ln L_1 - \beta\varphi \ln L_2 + (1-\ \varphi)\beta \ln N + (1-\ \varphi)\beta \ln B) + \frac{\alpha(1+\eta)-\eta}{\eta}\ln K + \frac{(1+\eta)}{\eta} lnU - \frac{1}{\eta} lnV \qquad (17'')$$

In our model there is heterogeneity in abilities, capital income, and labour endowments. The implied tax conflict described above may reduce the likelihood of catching up if public investment suffers as shown by the variable $\kappa\tau$, which has a negative effect on the growth of *K* in (17''), but a positive one on the terms of trade in (18') because taxes reduce supply, and also a positive one on the growth of *B* in (9'''). Catching up depends upon having well-balanced public and private capital stocks because of diminishing marginal returns for both in the production functions and investment rates close to those of a golden rule.

Equations (9'''), (18') and (17'') form a system that we could in principle try to estimate directly or use as a guidance for a vector-error-correction model, with right-hand side variables $(\ln K\,, \ln B; t, ln\ s, \ln(\kappa\tau), \ln\ (1-\tau), \ln N, \ln L_1\,, \ln L_2\,, ln\ Z)$, the same list of arguments for $\ln p$, but *s* and *Z* not in (9''').

One crucial policy question is that of the level of the tax rate τ. Its partial effect is to increase the growth of *B* in (9''') and the level of p in (18'), but to decrease the right-hand side of (17'') for capital accumulation. In all three equations the level of *B* works in the opposite direction of what the tax rate is doing. The tax and the public capital stock therefore have to be well-balanced. The static efficiency criterion of equal net marginal products of private and public capital is fulfilled under a golden rule: $\alpha Y/(pK) - \delta = \partial Y/\partial B - \theta = (\partial Y/\partial H)(\partial H/\partial B) - \theta = (\partial Y/\partial H)(\partial(\sum H_i)/\partial B) - \theta = (\beta Y/H)[\sum(1-\phi) H_i/B] - \theta = (\beta Y/H)[(1-\phi) H/B] - \theta = \beta(1-\phi)\ Y/B - \theta$. This equation is fulfilled if a share α of *Y* is invested in *K* and a share $\beta(1-\phi)$ of *Y* into *B* and both growth rates are equal. This first condition is exactly the golden rule that investment shares should equal elasticities of production of capital. The growth rates will be equal for *K/p* and *B* in the steady state derived above. Without golden rule there may also be static efficiency under equal growth rates but on a level of growth with less than maximum possible consumption per capita. It is not obvious though whether countries can reach an internal agreement on the conflicts how to tax and spend the revenues.

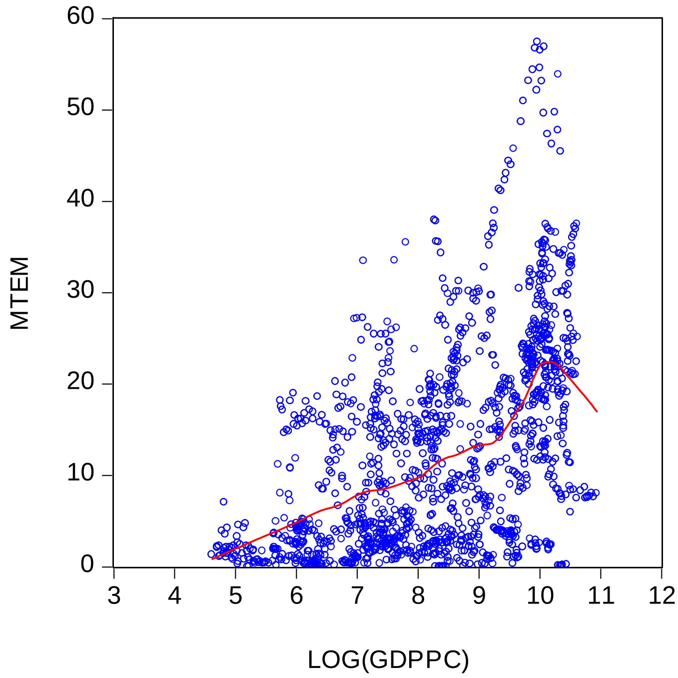

Figure 5. Absence of a machinery and transport equipment sector is possible at all levels of GDP per capita up US $32.500.

4.2 **Country selection**

Taking our model literally it should be applied only to countries that have no machinery sector. Figure 5 shows that countries at all levels of GDP per capita from $100 to $32500 may have no production of machinery and transport equipment expressed as a share of manufactures (MTEM) in the period 1990-2007. Similarly, using a nearest-neighbour fit, Figure 6 shows that there is a minimum of two years of schooling to have a machinery sector. However, countries with more years of schooling have a larger share of machinery. Then countries should be chosen which really have essentially no sector for machinery and transport equipment. These are Bolivia, Burundi, Cambodia, Cameroon, Gabon, Honduras, Mongolia, Nepal, Paraguay, Qatar, St. Lucia, Swaziland, Trinidad and Tobago, and Yemen. They all have less than one percent of manufactures in machinery and transport equipment. In addition it is not always clear that 'not available' is strictly distinguished from zero in the data. Countries with no data available may also be candidates. One country with no machinery sector and a good availability of data is Trinidad and Tobago. It is for this latter reason that we focus on T&T. The sector for machinery and transport equipment was only 0.27 % of value added in manufacturing in 2006 (World Bank, 2013).

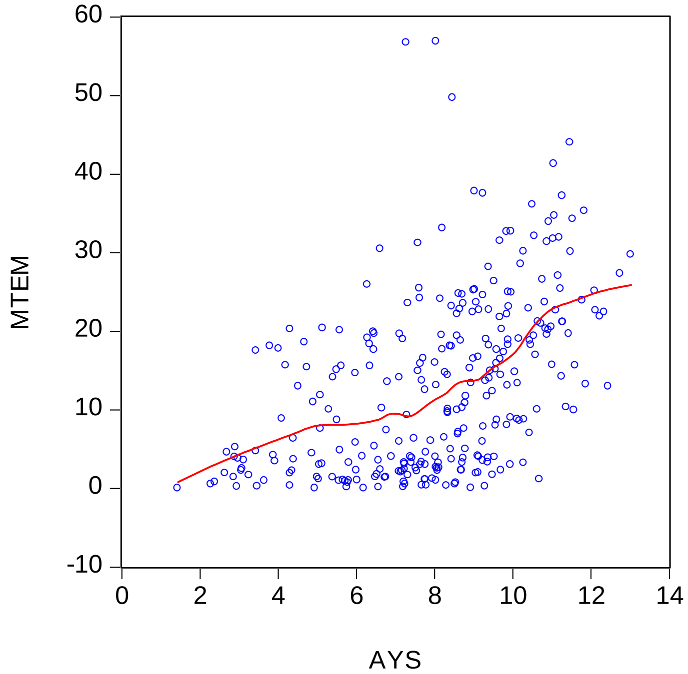

Figure 6. Absence of machinery and transport equipment sector is possible until 9.3 average years of schooling.

4.3 **Data**

We construct a data set ranging from 1961 to 2007, the year in which the data of Gupta et al. (2014) end. Private and public capital series as a share of GDP come from Gupta et al. (2014), who have made the data in line with and without the efficiency adjustment reasoning of Pritchett (2000) and the PIMI index of Dabla-Norris et al. (2012).[19] However, accepting Pritchett's (2000) concept is one thing and using the Public Investment Management Index for the efficiency adjustment is a different one. Gupta et al. (2014) use values of κ in the interval of 0.26 and 0.31 meaning that only these percentages of public investment data actually are assumed to go into public capital. The consequence of this is that since 1986 the efficiency adjusted capital stock is stagnating for Trinidad and Tobago. In contrast, the growth rates of the dis-aggregated public capital stock items in physical measures until 2007 all have positive growth rates, which are all larger than those of the non-adjusted capital stock (see Table 1)[20]. This is a clear argument against the use of the PIMI type of efficiency adjustment capital for Trinidad and Tobago. A reason for this may be that Trinidad and Tobago scores fairly high on the selection component of the PIMI index and this may be the better indicator for public investment valuation. Any other adjustment would also lead to lower growth rates of public capital, which seems undesirable because public capital in the case of Trinidad and Tobago has already a lower growth rate

[19] An approach using dis-aggregated rather than macro variables of public capital and investment is taken by Straub and Terada-Hagiwara (2011).

[20] In addition, access to electricity for 2010 and 2011 is 99 percent. These are physical indicator of supply. Fay et al (2017) discuss inefficiency of spending and use.

than all the physical items.[21] By implication, we have no reason to use the efficiency adjusted data for Trinidad and Tobago and we rather use the non-adjusted data. Oil rich countries can compensate civil servants easily and threaten them to get fired when corruption is detected. This can avoid corruption via public investment even if managers have a negative opinion on procedures. This is in line with the resource curse literature which would argue that resource rich countries with weak institutions run into the curse whereas those with good institutions may have a good growth performance. Trinidad and Tobago did join the ranks of the rich countries with strong growth of public capital, both indicating that their institutions are not likely to be too bad.

Table 1: Growth of Public Capital items in Trinidad and Tobago until 2007		
Public capital item	Period (a)	yearly growth rate (b)
Fixed broadband Internet subscribers (per 100 people)	2002-2007	1.056314
Internet users (per 100 people)	1995-2007	0.443273
Mobile cellular subscriptions (per 100 people)	1991-2007	0.506871
Secure Internet servers (per 1 million people)	2001-2007	0.248872
Telephone lines (per 100 people)	1990-2007	0.032509
Liner shipping connectivity index (maximum value in 2004 = 100)	2004-2007	0.013385
Container port traffic (TEU: 20 foot equivalent units)	2000-2007	0.085668
Roads, paved (% of total roads)	1990-2007	0.009885
Efficiency adjusted public capital	1990-2007	-0.00012
Non-adjusted capital	1990-2007	0.011804
Source: World Development Indicators; author's calcuations		
Notes:		
(a) Starting date limited in WDI; final date chosen as data in Gupta et al. (2014) end here.		
(b) Calcuated as log difference of first and last observation divided by number of years		

Gupta et al.'s data is in percentages of real GDP. To convert the percentages to capital stock values, the series have been multiplied with GDP series taken from the PWT 6.3 (Heston et al. 2009), which uses Laspeyres indices. Taking differences of the stocks yields the net investment and adding depreciation yields gross investment. Gupta et al. (2014) assume that the depreciation rate for middle-income countries increases monotonically at a constant rate from 2.5 percent in 1960 to 4.3 percent in 2010. Following this argument we obtain the efficient public investment or tax rate of our model as

$$\kappa\tau_t = \frac{B_t - (1-\delta)B_{t-1}}{Y_t}$$

Here $\kappa\tau$ is public investment as a share of GDP, B is public capital, δ is the depreciation rate and Y denotes GDP. The savings rate s can be calculated according to (2) as private gross investment divided by $(1-\kappa\tau)Y$. Using the non-adjusted data implies that we use the case $\kappa = 1$.

[21] A second point raised by Pritchett (2000) is that too high values of unadjusted public capital growth rates lead to too low values of total factor productivity growth rates. He does not include Latin America and the Caribbean into the list of problem areas. In line with that we do not find support for that argument for Trinidad and Tobago (see appendix 'Growth accounting'). Similarly, Hurlin and Arestoff (2010) compare the growth of physical indicators with that of investment variables and confirm the results of Pritchett for four countries. Unfortunately, Trinidad and Tobago is not included in the list.

Terms of trade are constructed as 'Exports as a capacity to import' divided by 'Exports of goods and services', both in local currency units. The data is taken from the World Bank (2014).

The labour force is separated into two parts; labour in production, L_1, and labour used in the acquisition of human capital, L_2. For the L_1 series we use the total labour force series from the World Bank (2005, 2013).

The second series, L_2 is approximated by years of schooling. Barro and Lee (2013) provide average years of schooling for Trinidad and Tobago at 5 year intervals from 1950 to 2010. For the present purpose we interpolate the series using cubic spline interpolation to obtain a complete series.

World income (in constant 2000 US$) and the GDP growth rate are taken from the World Bank (2013).

Unit root tests based on ADF (augmented Dickey-Fuller) equations with break point selection suggest that only consumption per capita has a unit root for sure. For some other variables this result is found when applying some lag length criteria applying many lags in the tests but not for others applying criteria with a low number of lags. In line with the suggestion to choose against unit roots because of the low power of the tests for a low number of observations (see Juselius et al 2014) the cautious interpretation is to assume only one unit root from these tests.

We have made some possibly over-simplifying assumptions, which can be avoided using a vector-error correction model. First, export and production functions may not be of the Cobb-Douglas type.[22] Second, population growth, savings and tax rates or inefficiency parameters may not be exogenous and constant. Third, export revenues may be spent also on consumption goods and tax revenues may come from other sources and get used for other purposes than just public investment. Therefore we drop the CD functions as well as output and export quantities from the empirical analysis in this section. Fourth, budgets need not be balanced but rather we could have foreign debt if investments exceed savings and government debt if tax revenues fall short of public expenditure. Fifth, there are country specific factors, which theoretical models normally omit. In the case of Trinidad it is the high share of oil in the exports. The energy sector contributes 66% of exports, 44% of GDP but only 3.1% of the employment of the country, which has a Herfindahl concentration index of exports of below 0.25 (Longmore et al. 2014). An implication of this is that we use an exogenous oil price whereas prices of other exports may be endogenous as in the theoretical model.

4.4 A vector-error correction model

In addition to the eight endogenous variables listed after equation (17'') we include consumption as net income after subtracting savings ratios for public and private capital, $C/P = Y(1-s(1-\tau) - \tau)$[23], and use the factors of production instead of gross income as regressors in the VECM. Testing for lag

[22] Baffes and Shah (1998) use a translog function instead of the CD.

[23] Note that the interest here is not included in net factor income from abroad and consumption financed by that but rather only in the consumption creating effect of public investment or capital via GDP after paying taxes.

length and stability shows that a VAR with two lags is stable, but not with more lags. The log levels rather than the growth rates of world income and oil prices are exogenous – otherwise the VAR is not stable.[24,25] When setting up a vector-error correction model, we treat the first 9 variables as endogenous, which is confirmed by finding statistically significant adjustment coefficients in a VECM. We include a constant and a quadratic time trend into the VECM in order to avoid growing growth rates from the exogenous log levels and because they are statistically significant. VECMs have the highest log-likelihood for 8 cointegrating equations.[26] This is consistent with the fact that the number of endogenous variables $K = 9$ with the number of cointegrating equations $r = 8$ yields $K - r = 1$ unit roots which is in line with the uni-variate finding reported above that only one variable has a unit root. The statistically insignificant adjustment coefficients remain unrestricted. The long-term relations are identified as follows[27], with *t*-values in parentheses with those for constant and trend only at the end of the complete VECM in the appendix:

$$CE1: E(u_1(-1)) = LOG(CPC(-1)) - \underset{[-119.6]}{2.9}LOG(P(-1)) + 0.0457t - 11.57 \quad (28)$$

$$CE2: E(u_2(-1)) = LOG(K(-1)) - \underset{[-35.68]}{0.58}LOG(S(-1)*(1-TAU(-1))) - 0.044t - 24.3 \quad (29)$$

$$CE3: E(u_3(-1)) = LOG(B(-1)) - \underset{[-48.0]}{0.8}LOG(TAU(-1)) - 0.042t - 24.5 \quad (30)$$

$$CE4: E(u_4(-1)) = LOG(P(-1)) - \underset{[-39.7]}{5.07}LOG(LF(-1)) + 0.0757t + 64.3 \quad (31)$$

$$CE5: E(u_5(-1)) = LOG(AYS(-1)) - \underset{[-30.3]}{0.085}LOG(B(-1)) - 0.0078t + 0.19 \quad (32)$$

$$CE6: E(u_6(-1)) = LOG(S(-1)*(1-TAU(-1))-\underset{[22.5]}{2.13}LOG(CPC(-1)) - 0.01t - 17.3 \quad (33)$$

$$CE7: E(u_7(-1)) = LOG(TAU(-1)) - \underset{[-47.47]}{0.723}LOG(S(-1)*(1-TAU(-1))) - 0.01t +0.978 \quad (34)$$

$$CE8: E(u_8(-1)) = LOG(LF(-1)) + \underset{[22.9]}{0.2}LOG(POP(-1)) - 0.02t - 15.24 \quad (35)$$

[24] Giles and Williams (2000) explain extensively why and how trends and lags have to be chosen with utmost care and not just by mere assumption.

[25] Stability with two lags requires entering the exogenous variables world income and oil prices in the form *t*d(log(X))*. This formulation enables us to better explain the formulation for shocks on the growth rates of world income and oil prices below. Under the standard formulation for log levels stability happens to occur with only one lag in the VAR.

[26] Note that standard tests are not adjusted for exogenous variables with two exceptions we cannot use here: For the case with exogenous I(1) variables critical values are not available because those in Harbo et al. (1998) have been derived only for $T = 400$ and those in Pesaran et al. (2000) for $T = 500$.

[27] The abbreviations are as follows. *CPC* is consumption per capita, *K* private capital, *B* public capital, *P* terms of trade, *AYS* average years of schooling, *S(1-TAU)* share of investment in private capital; *TAU* share of investment in public capital, *LF* labour force, *POP* population, and time trend *t*.

As the expected value of the left-hand side is zero, for the interpretation all variables but those with unit coefficients could be written to the other side to get the standard equation form. This would change the signs of the coefficients. The interpretation of the partial effects, as opposed to the complete solution used below, of the long-term equations is as follows. (28) relates consumption per capita positively to the terms of trade as in basic trade theory and in our growth model. (29) indicates that the capital stock is higher if the net savings ratio is larger. (30) relates public capital to its investment ratio. According to (31) the terms of trade and the labour force grow in proportion to each other, which is plausible if both are pulled by exports. (32) relates public capital to human capital; we have a well-functioning complementarity between private capital and public investment here for Trinidad and Tobago. (33) indicates that at a higher consumption per capita more net savings are possible. (34) indicates that public and private capital have higher investment have a complementary relation as the stocks do in equation (32). Finally, (35) indicates that the labour force is lower if the population is higher; this simply reflects the fact that labour force growth is positive and population growth is negative. The long-term relations *CE1-8* are part of the following complete system (*Z* is world GDP, *proil* is price of oil, t-values in parentheses):

$$dy = A(CE) + Bdy(-1) + Cx. \qquad (36)$$

Here *dy* is the (9, 1)-vector (9 rows, 1 column) of first differences of the variables appearing first in the *CE*s and the growth rate of the population. *A* is the (9, 8)-matrix of adjustment coefficients and *CE* is the (8,1)-vector of cointegrating equations (28)-(35); *B* is the (9, 9) matrix of coefficients of the (9, 1)-vector of first differenced terms. C is the (9, 4)-matrix of the coefficients of the vector of exogenous variables *x'= (c, t, d(log(Z))*t, t*d(log(proil)))*.[28]

The period is 1962-2006. We do not put constraints on the adjustment coefficient if they have low t-values. Adj. R-squared for the nine equations are 0.69, 0.9, 0.95, 0.35, 0.99, 0.53, 0.14, 0.62, and 0.91.

Some interesting aspects that merit interpretation are the following. First, oil prices have an impact on the terms of trade growth as in Watson (2003) and also on the education equation, *d(log(ays)), because "most of the government revenues come from oil and gas…"* (Artana et al. 2007). Second, world income growth, *d(log(Z))*, has its strongest impact on growth of education with a positive sign. All dependent variables are related to cointegrated equations through to some statistically significant adjustment coefficients implying that no variable is weakly exogenous. Clearly, the weak point in terms of adjusted R-squared is the equation for public investment, because this is a highly political decision. But it should also become clear from this that public investment is endogenous. In a VECM,

[28] For the matrices of coefficients see Appendix of the working paper version.

public capital reacts to past variables rather than pushing in the possibly false expectation of a big push (Warner 2014).[29]

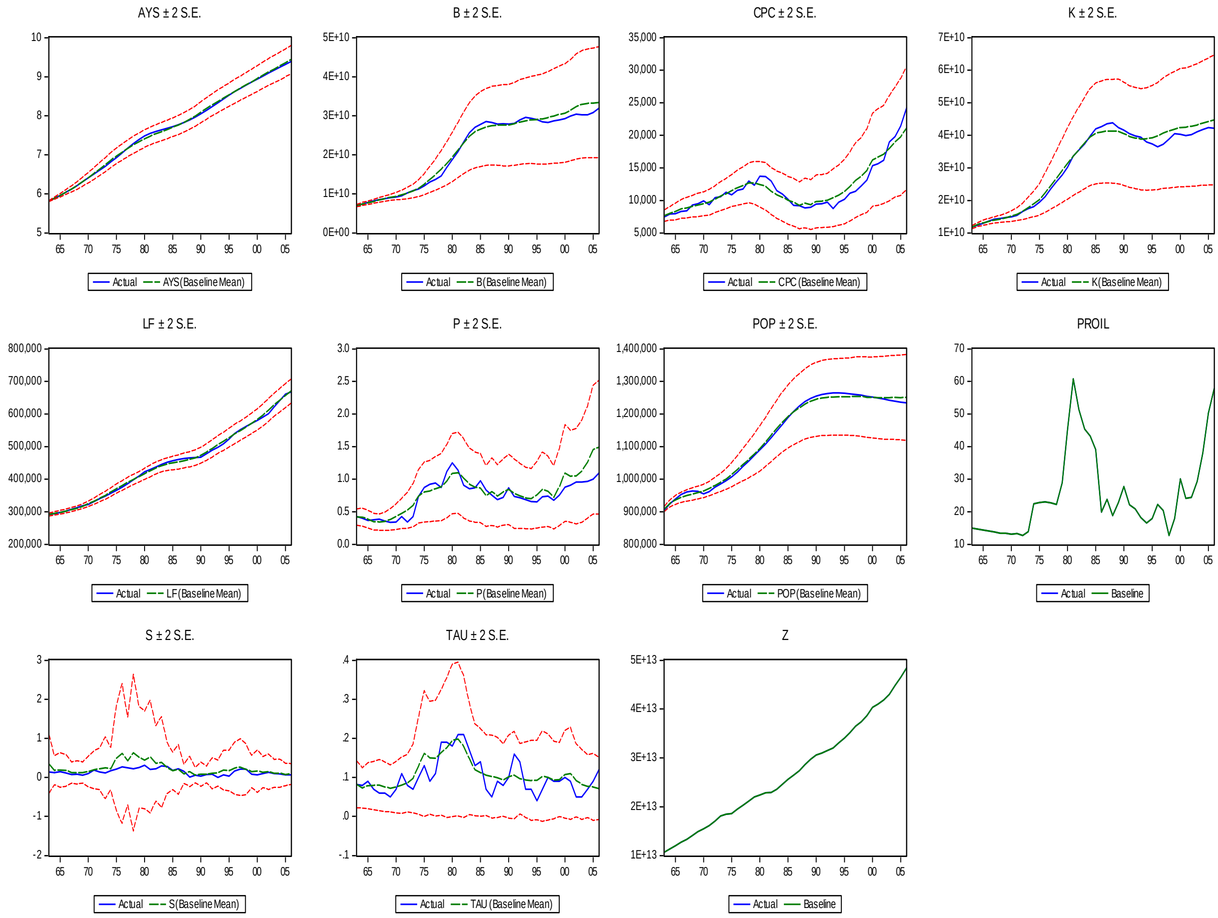

Figure 7 Baseline simulation of the VECM.

A thousand baseline runs of a dynamic stochastic solution through the Broyden algorithm, using the bootstrap method for innovation generation and calculating the confidence interval from the whole sample, show in Figure 7 that the data are never outside the confidence interval. Public capital reaches its maximum during the 1990s. The standard interpretation in the literature would be that once a reasonable level of public capital is reached, public investment would be limited to maintenance and repair, the depreciation, with little net investment. Here, in addition, this flattening goes together with oil prices falling from 1981 to 1998, a pattern very similar to that of the terms of trade shown in the figures below. In contrast, average years of schooling keep growing. Unlike African countries (see Yepes et al. 2008) oil revenues are reported - in line with our results in Table 1 - to be channelled into infrastructure investment and resource-based industrialization in Trinidad and Tobago (Gelb 1988) in connection with a special fund abroad that gets 50-70 percent of the oil windfalls since 1974, the rest being used for current consumption and investment (Auty and Gelb 1988). As we model growth ideas, the baseline simulation of Figure 7 shows some serial correlation from cycles, but this leads to a bias

[29] Critical masses as for telecommunication networks can be achieved either way.

only if the serial correlation is very strong (Epple and McCallum 2006). World income growth is clearly growing but oil prices show ups and downs which are not necessarily upward trending. Confidence intervals for savings ratios are getting very large at moments of oil crises, and Latin American and Asian debt crises end of the 1970s, beginning of the 1980s and 1997/8.

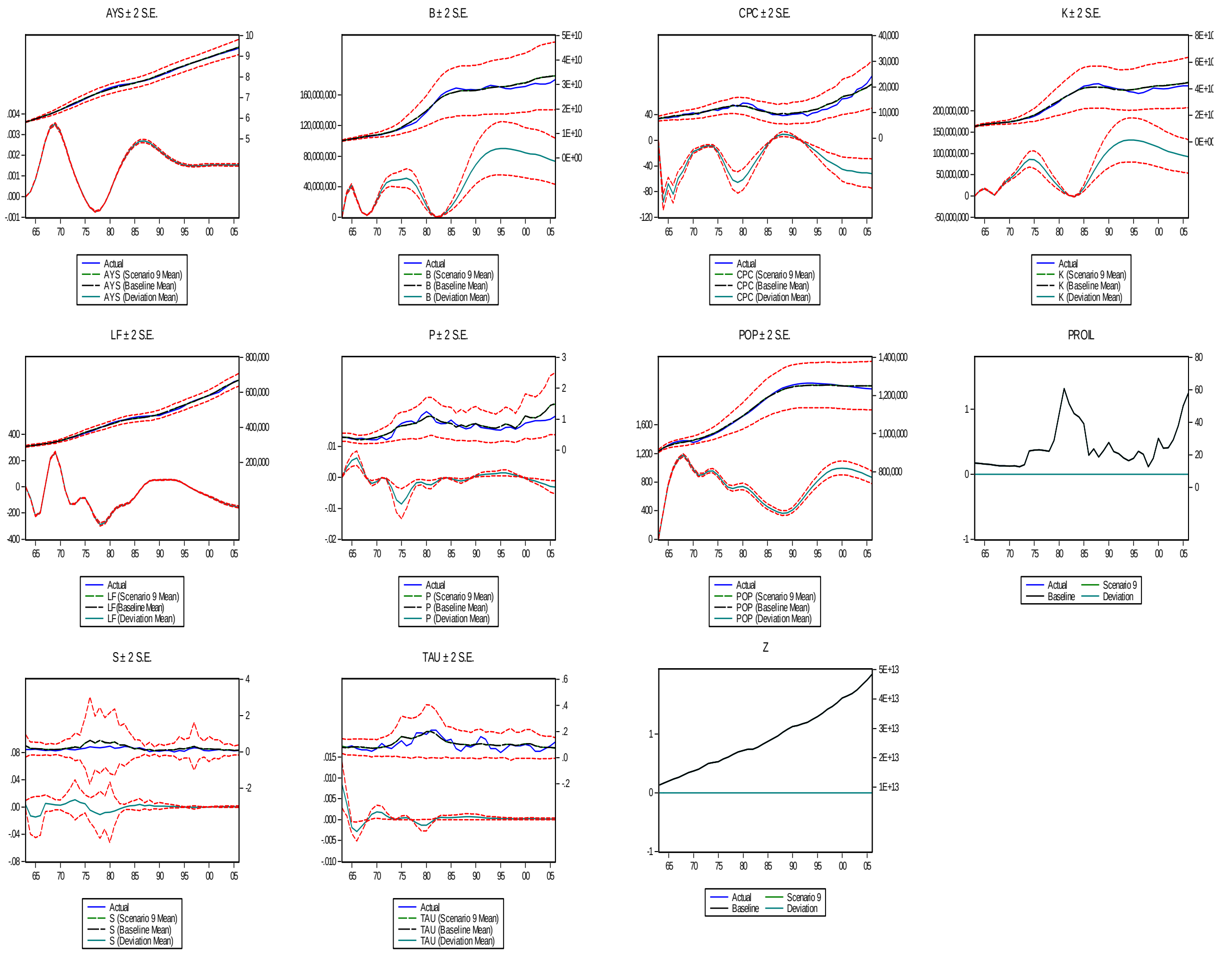

Figure 8 Effects of a temporary shock of public investment on the economy. Levels on the right-hand scale; changes from baseline on the left-hand scale for the lower curve. Confidence intervals are for alternative scenario and its deviation from baseline.

4.5 Transitory and permanent shocks

An important question is whether an increase in public investment can bring the country to a higher level of welfare. Such an increase can come as a one-time increase that then goes its way through the dynamic system, a case that can be seen frequently in our data, or it can come as a permanent increase. The first version can be captured by a one-time shock to the residuals and the second by a permanent shock to the intercept of the equations. Moreover, shocks to world income growth and oil prices can give insights on the working of the empirical model using the theoretical model for the explanation.

Figure 8 shows the effects of a temporary shock to public investment of 0.1 for tau, which is closer to a gradual phasing in than to a big push.[30] It has a slightly positive permanent effect on public investment as a share of GDP even for the lower bound and increases public capital, followed by a slightly smaller increase in private capital. The effect on years of schooling are slightly positive, and for the labour force fluctuating in the beginning and zero in the long run average. For population the increase is positive but less than for public and private capital and schooling. By implication, per capita GDP and productivity increase at a lower percentage than the capital stocks. These results are qualitatively similar to those of de Frutos and Pereira (1993). We should not draw the conclusion though that this justifies carrying out this policy, because per capita consumption falls. The increase in GDP per capita is less than that in taxes paid and private capital invested. For households the rate of return here is negative because the level of public capital is already high (see also Eden and Kraay 2014). The terms of trade are first higher for six years and then lower for 21 years and keep going down and up. Temporary shocks for years of schooling look very similar and therefore are not shown. Temporary shocks to public capital stocks have weak effects fluctuating around zero for all variables. Warner (2014) argues strongly against growth effects from public investment booms and also against complementarity effects of public and private capital. The latter is clearly present here and supported by Eden and Kraay (2014) for most poor countries. Warner uses a cross-section regression with lags but no dynamics as it could come at least from lagged dependent variables, if not from true dynamics as modelled in our paper. In addition, he does not use a tax or revenue variable which might absorb some of the negative effects (Blankenau et al. (2004), Straub and Terada-Hagirawa (2011)) without or with non-linearity as in Fosu et al. (2016). As Warner addresses mainly big push models, he should also use econometric threshold models and take into account the network related critical mass literature (Daido and Tabata 2013; Agénor and Neanidis 2015). In particular, Daido and Tabata (2013) show that development may be successful if firms decide upon their investments before governments do, although this creates additional problems of forming expectations regarding public investment. The major problem therefore may be not whether we have a big push or a leading government, but rather that the government may not follow the needs of firms or only too sluggishly so. In contrast, Presbitero (2016) reports cases of too quick increases of public investment leading to weak effects in connection with a lack of absorptive capacity. In our theoretical model this would be captured by a low elasticity of production of public capital in human capital formation. However, we do not find this in the evidence for Trinidad and Tobago where years of schooling and private capital grow nicely in proportion with public capital after a shock. Results may differ by country, of course, also after taking into account all of these aspects. We fully agree with the practical value of Warner's five major

[30] As we deal with transitory shocks one-by-one and not several jointly there is no issue of Cholesky ordering.

problems discussed on page 65 of his paper. On the other hand, the damages from lack of infrastructure, the problems from poor management and the necessity to improve both in a well-timed manner are nicely described by Nielsen and Lofgren (2011). This can better be captured by modelling a permanent change as is done here next. From the long-run level effects of the temporary shock in figure 8 we can conclude that the data reject the idea that we might have a merely exogenous growth process for Trinidad and Tobago, as exogenous growth models have no permanent effects of temporary shocks (Kocherlakota and Yi 1996).

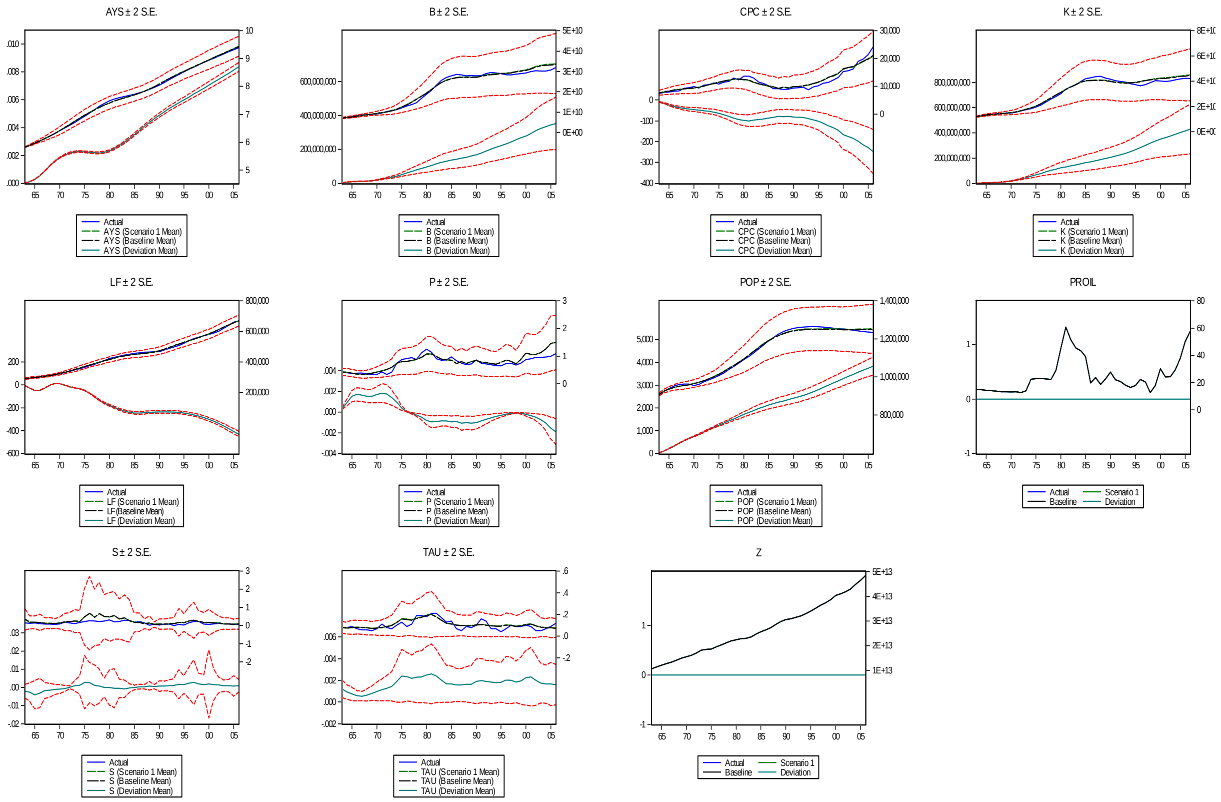

Figure 9 Effects of a permanent shock of public investment, TAU, on the economy. Levels on the right-hand scale; changes from baseline on the left-hand scale for the lower curve. Confidence intervals are for alternative scenario and its deviation from baseline.

Figure 9 shows the effects of a permanent increase of the tax or public investment rate by *0.01,* called scenario 1, which is even more gradual than the temporary shock of Figure 8. The tax is higher throughout in scenario 1 compared to the baseline and so are human, public and private capital stocks.[31] As in the case of a temporary shock, labour variables react only weakly. Consequently, GDP per capita must be larger, but consumption per capita is lower because the increase in per capita GDP does not outweigh the increase in taxes. Again, less strongly increasing terms of trade indicate more strongly growing quantities of exports and increasing private capital stocks indicate that the value of

[31] Similarly, Bahal et al. (2015) show complementarity between public and private investment using a VECM for India in the post-reform period 1980-2012, but crowding out before. Their result is in line with Cavallo and Daudé (2011), who attribute crowding out to weak institutions.

exports used for capital imports is increased and points to a low price elasticity of export demand. The higher GDP then allows for more tax revenues and public investment. Figure 9 suggests differences in levels growing at a constant rate, implying no growth rate effects.[32] Trinidad and Tobago has a reasonably high public investment rate between 4% and 20% with a mean of 10% and a median of 9%. This is in the order of magnitude of Finland (see Luoto 2011) and what poor countries should have (see Fosu et al. (2016) for Sub-Saharan Africa, and Estache (2010, Table 2) for what is required according to international institutions' estimates). Countries with very good infrastructure, high population densities or high degrees of urbanisation may have lower optimal rates (Estache 2010; Esfahani and Ramirez 2003). In China public investment also has increased the GDP but without decreasing consumption per capita (see Chen and Yao 2011).

Enhancement of human capital through permanent shocks (not shown) do increase years of schooling, public and private capital and therefore, with slightly falling labour, GDP per capita, but not consumption per capita. This could only happen if human and public capital get more efficient or more productive. Whether and how these effects can be obtained seems to be unclear so far. The implicit message in Gupta et al. (2014) would be that bureaucracy costs of public capital could be decreased without net disadvantage requiring less of an increase in public investment. For human capital the question regarding TTO would be whether or not its use can be improved on the supply side and on the absorbing demand side (Longmore et al. 2014). As human capital is moving out (brain drain is more than 70 percent of tertiary abroad) the problem seems to be more on the demand side; Artana et al. (2007) point to a lack of business opportunities and also to a lack of a "… culture of innovation to drive productivity". Finally, diversification is most likely to happen in the non-traded sector, because it seems inevitable that the exchange rate fluctuates wildly with the oil price to an extent that newly exporting sectors are hardly able to digest. This intuition is also supported by the increasing rates of return for capital in the service sector and the history of a falling share in GDP of the non-petroleum tradable sector.

[32] In contrast, Agénor (2010) uses functions similar to (1) and (8) but with constant returns to all non-labour factors, public capital being productive in both, and *H* having a negative impact on the discount rate. A permanent shock to public investment, financed through foreign aid or a reduction of unproductive and not utility enhancing government expenditure, then leads to a higher steady-state growth rate. The model deserves merit as an interesting set of conditions for a big push. But the set of assumptions emphasized in this footnote also may be a bit optimistic.

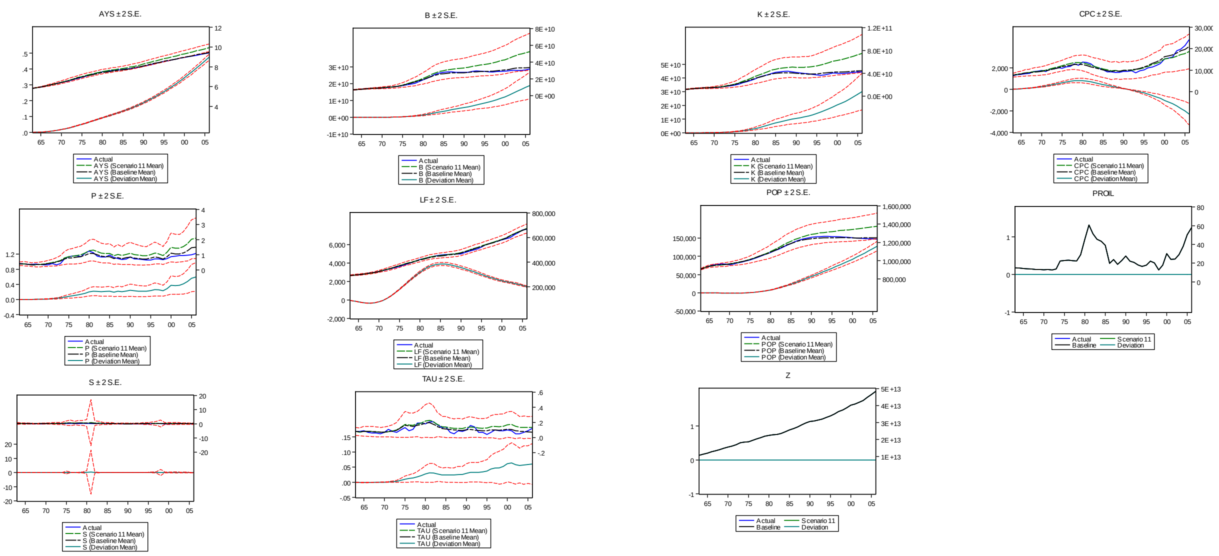

Figure 10. Effects of a one per cent shock to world income growth. Levels on the right-hand scale, changes on the left-hand scale starting from zero. Confidence intervals are for alternative scenario and its deviation from baseline.

A common question of balance-of-payments-constrained growth models, including Keynesian and neo-classical two-gap and Prebisch-Singer models is what a shock of world income growth does to the economy. We add a permanent shock to all equations of (36). The size of the permanent shock is 0.01 multiplied by the coefficients *c(k,3)*t* of *dlogZ* in these equations, which is equivalent to adding 0.01 to the growth rate of world income. The result compared to baseline is shown in Figure 10. The terms of trade are increasingly higher. Capital stocks are also increasingly higher, indicating that higher terms of trade are not turned into lower export quantities by high price elasticities in a way that might outweigh the effect of world income on exports. In particular, public capital which partly goes into education goes up as in some historical periods of Brazil (Musacchio et al. 2014). Also it indicates that exports are not predominantly used for other imports like consumption or intermediates. Savings ratios hardly react except for some strong ups and downs in the middle phase – as in the previously shown shocks - indicating that the investment stems from an increase of output and its effects on savings. Public investment does react and therefore public capital follows the private stock. Population increases strongly, probably through immigration (as in Figures 8 and 9), which is plausible if Trinidad and Tobago is making better use of world economic conditions through higher income elasticities of export demand. Consequently, the labour force also grows beyond baseline, although average years of schooling follow the better prospects of the economy and should therefore partially reduce labour supply. In total, consumption per capita is then larger than before for about thirty years. As public and private capital stocks increasingly grow apart, we have the growth rate effect that appears in our growth rate formulas for the long run and the data, that private capital grows more quickly than public capital and under the world income shock this is reinforced because more quickly growing exports buy more quickly growing capital whereas public capitals draws on consumption via taxes. The extreme uncertainty in the gross savings rate happens to occur in 1979, the year when restrictive monetary policy starts in the USA.

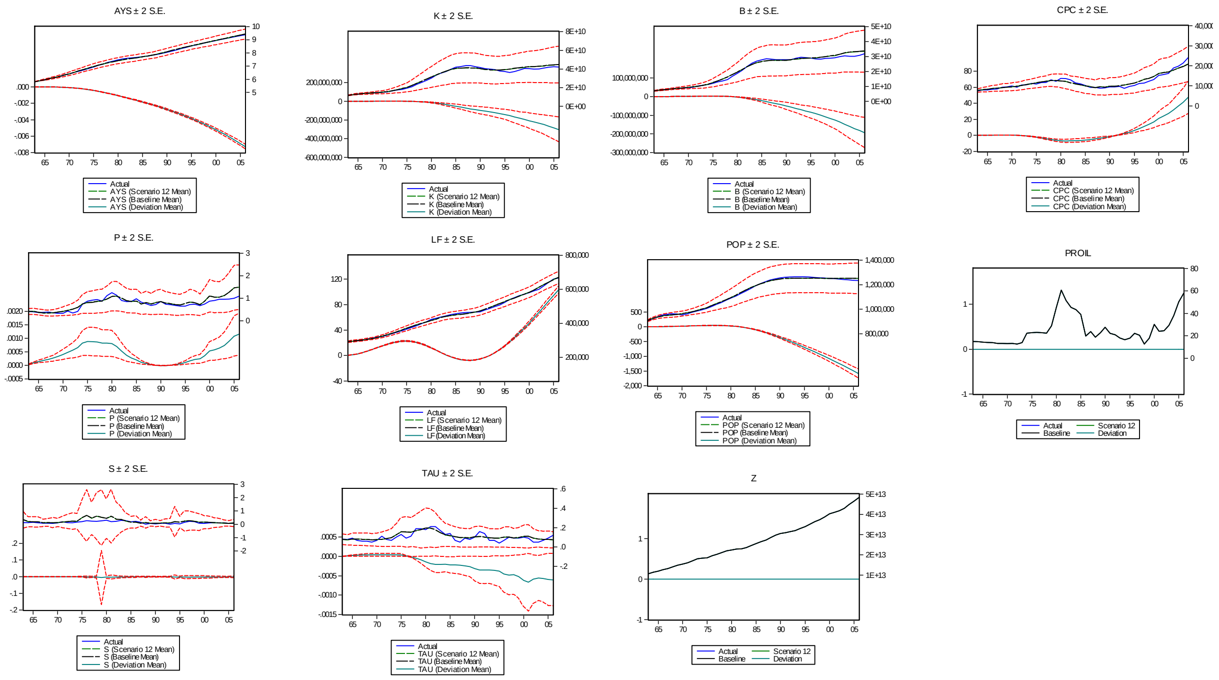

Figure 11. Effects of a one per cent shock to oil price growth. Levels on the right-hand scale, changes on the left-hand scale starting from zero. Confidence intervals are for alternative scenario and its deviation from baseline.

Finally, an oil price shock is in principle positive for sellers but negative for consumers. We implement it as a permanent shock of a one per cent increase in the oil price growth rate by way of adding the coefficient *c(k,4)*t* of the oil price growth variable multiplied by 0.01 to all equations in (36). The result is presented in Figure 11. Terms of trade increase more than before with ups and downs similar to those of the oil price. A slightly weaker increase in the capital stock indicates that exports increase less strongly and/or other goods are imported; differences in capital growth do not have the same shape as that of the terms of trade difference. Public capital follows private capital again and so do public investments and average years of schooling, but all downwards now. Labour force growth and population growth go up though in the long run, perhaps through migration, and stimulation of the non-traded goods sector. Consumption per capita is going up through this and imported consumption goods. Oil price increases seemingly stimulate consumption and labour but not human, public and private capital. This suggests that producing oil is more important than buying oil.

In Figures 8-11 terms of trade are clearly endogenous, reacting to supply, demand and the oil component and the assumption of exogenous terms of trade is clearly oversimplifying as admitted by Worrell et al (2013).

All interpretations of shock scenarios are in line with the theoretical model, although the model is extended to include oil prices because of its relevance for Trinidad and Tobago. Moreover, a permanent shock to public investment, unlike to that from world income growth, seems to have level effects rather than growth rate effects, which suggests that we do not have an endogenous growth model (see Kocherlakota and Yi 1997) behind the data of Trinidad and Tobago.

As the permanent level effects of temporary shocks exclude the possibility of an exogenous growth model and the permanent effect on the level rather than growth rate of permanent shocks exclude the possibility of an endogenous growth model, the data of Trinidad and Tobago must be driven by a semi-endogenous growth process.

5. Summary and conclusion

We have merged two growth models with a semi-endogenous growth mechanism; a human capital augmented model with non-rivalrous, possibly efficiency-adjusted public capital and a model with imported capital goods, limited export demand and endogenous terms of trade. The non-rivalry in the use of public factors in connection with the different abilities of household to form human capital leads to different preferred rates of public investment and a strong role for policy to decide on public investment. By implication, public investment may be threatened by tax resistance. The model is relevant for countries without machinery sector and without much R&D. It shows how investment in public capital enhances exports and how export demand helps financing public capital. Therefore it is the first to integrate two empirical strands of literature into growth theory, a large one on public investment enhancing trade volumes and a small one on trade allowing financing public investment. The model has three major driving forces: exogenous technical change, the growth of the number of households with access to public capital and the world income growth. Depending on whether the supply side forces or the demand side are growing more quickly, terms of trade may rise or fall in the long run. In the transition to the steady state public investment inefficiency possibly distorts the allocation against public investment leading to more private investment, consumption, and exports and lower terms of trade.

We have used the major variables of the model in a panel VAR for Sub-Saharan Africa for the motivation and in a vector-error correction model with data for Trinidad and Tobago, which has hardly any machinery sector or R&D but has reached the ranks of the high-income OECD countries recently and therefore must have spent the oil money well. Moreover, the growth rates for public capital without efficiency adjustment are lower than for all physical real capital data for ports, roads, internet and telephones. Therefore we do not use the efficiency adjusted data of Gupta et al (2014) based on the PIMI index, which make the growth rates of public capital even lower. The vector-error correction model is enhanced by oil prices, because Trinidad and Tobago has a strong oil sector. Thus, we contribute to the empirical dynamic simultaneous equation literature adding a prominent role of world income growth, oil prices and the terms of trade.

Transitory and permanent shocks to public investment increase public and private capital as well as education permanently and therefore also the GDP per capita, but the effect is too weak to outweigh the negative effect of taxation on consumption per capita. The reason is that public investment shares are already high in Trinidad and Tobago and therefore should not be increased. In addition, higher public investment reduces export quantities and increases the terms of trade sufficiently much to allow for buying more capital goods. The latter effect points to price inelastic exports.

Permanent shocks to the growth rates of oil prices and world income show that higher trade volumes lead to more imported capital goods, higher GDP, more tax revenues, higher public investment, more public and private capital and consumption per capita. However, oil price growth increases lead to more consumption and less human, public and physical capital.

As transitory shocks on public investment have level effects the VECM with data for Trinidad and Tobago does not follow the logic of an exogenous growth model, and because permanent shocks have level effects but no growth rate effects we do not find reactions which are typical of endogenous growth models. By implication, the data support a semi-endogenous growth model for Trinidad and Tobago with all the mechanisms of our theoretical model.

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Appendices

Appendix Evidence for the effect of public investment on international trade

Bougheas et al. (1999) show that the length of the motorway network in kilometres and aggregate public capital including non-transport indicators have a positive impact on the export volume of nine EU countries. Limão and Venables (2001) show that infrastructure reduces transport costs related to Baltimore, and reduced transport costs enhance the trade volume. Clark et al. (2004) show that infrastructure reduces shipping costs to the USA, which in turn increases trade volumes at the 6-digit Harmonized system level. Nordas and Piermartini (2004) show that road, port, airport and telecommunication infrastructure have an impact on total bilateral trade, differing in strength by sector, in a cross-section of countries for the year 2000. Wilson et al. (2005) show that service infrastructure increased the trade volume in 75 countries in 2000-2001 through the reduction of telecommunication costs. Brun et al. (2005) show that trade volumes increase between 1962 and 1996 for a large sample of 130 countries when an interaction variable of time and distance is used as a control variable. Iwanow and Kirkpatrick (2007) show that an infrastructure index has an impact on the trade volume that is twice as large for developing countries as for the whole sample of 78 countries for the years 2000-2004. Granato (2008) shows that a principal component of production infrastructure increases exports of Argentinian regions between 2003 and 2005. Shepherd and Wilson (2009) show that port infrastructure enhances trade of the fuel sector and air transport infrastructure enhances trade of all sectors but fuel and food. Donaldson (2012) shows that railroads, via a distance measure, have a positive impact on the exports of 17 commodities from 45 regions in colonial India from 1880-1920. Portugal-Perez and Wilson (2012) find a positive impact of ICT (information and communication technology) and a physical infrastructure index including airports, seaports, road and railroads on bilateral trade of 101 countries for the period 2004-2007. Francois and Manchin (2013) show the impact of principal components of infrastructure indicators on bilateral export and import data from 149 countries. Vijil and Wagner (2012) using a similar index for infrastructure show for a cross-section of up to 96 developing countries that infrastructure has a positive effect on export values and export/GDP ratios. Volpe Martincus et al. (2012) show that distance changes through road construction have an impact of Peruvian firm exports. Goswami (2013) showed that an infrastructure indicator including road density has a positive impact on trade volumes as a share of GDP in four South Asian countries because roads decrease transport costs. Albarran et al (2013) show that the extension of Spain's motorway network has increased the export probability of Spanish small and medium sized manufacturing firms. Akpan (2014) shows that road infrastructure enhances intra-regional trade among the ECOWAS[33] countries. Evidence for a positive effect of infrastructure, especially telecom, on exports of countries in Sub-Saharan Arica has been found by Harrison et al. (2014), and Mupela and Szirmai (2014). Meijers (2014) finds a positive effect of the percentage of

[33] Economic Community of West African States

internet users in the population on the openness ratio ((imports plus exports)/GDP) for 162 countries during the years 1990-2008. Mitra et al. (2014) see exports as the outcome of physical infrastructure and other factors in India. Donaubauer et al. (2014) show that a newly constructed global infrastructure index is positively correlated with openness in a panel of 140 countries. Coşar and Demir (2016) show that investment in transforming single lane roads into double lane roads in Turkey between 2003 and 2012 has increased the growth of trade from provinces to gateways.

Appendix Growth accounting

A second point raised by Pritchett (2000) is that too high values of unadjusted public capital growth rates lead to too low values of total factor productivity growth rates. In order to check this for Trinidad and Tobago we run growth rate accounting calculations in 16 different ways indicated in Table A1.

Table A1: Sixteen versions of growth rate accounting

g1=d(log(y)) -(0.1*d(log(b))+(1/3)*d(log(k))+(1/3)*d(log(l2))+(1/3)*d(log(l1)))

g1lag=d(log(y)) -(0.1*d(log(b(-5)))+(1/3)*d(log(k))+(1/3)*d(log(l2(-5)))+(1/3)*d(log(l1)))

g1oil=d(log(y)) -(0.1*d(log(b))+(1/3)*d(log(k))+(1/3)*d(log(l2))+(1/3)*d(log(l1))+0.089390*D(LOG(PROIL)))

g1lagoil=d(log(y)) -(0.1*d(log(b(-5)))+(1/3)*d(log(k))+(1/3)*d(log(l2(-5)))+(1/3)*d(log(l1))+0.098601*DLNPROIL)

g2 =d(log(y)) -(0.2*d(log(b))+(1/3)*d(log(k))+(1/3)*d(log(l2))+(1/3)*d(log(l1)))

g2oil=d(log(y)) -(0.2*d(log(b))+(1/3)*d(log(k))+(1/3)*d(log(l2))+(1/3)*d(log(l1))+0.085043*DLNPROIL)

g2lag =d(log(y)) -(0.2*d(log(b(-5)))+(1/3)*d(log(k))+(1/3)*d(log(l2(-5)))+(1/3)*d(log(l1)))

g2lagoil=d(log(y)) -(0.2*d(log(b(-5)))+(1/3)*d(log(k))+(1/3)*d(log(l2(-5)))+(1/3)*d(log(l1))+0.100204*DLNPROIL)

g3=d(log(y)) -((1/3)*d(log(k))+(1/3)*d(ays)+(1/3)*d(log(l1)))

g4=d(log(y)) -((1/3)*d(log(k))+(1/3)*d(log(ays))+(1/3)*d(log(l1)))

g3oil=d(log(y)) -((1/3)*d(log(k))+(1/3)*d(ays)+(1/3)*d(log(l1))+0.082192*d(log(proil)))

g4oil=d(log(y)) -((1/3)*d(log(k))+(1/3)*d(log(ays))+(1/3)*d(log(l1))+0.090937*d(log(proil)))

g5=d(log(y)) -(0.1*d(log(b))+(1/3)*d(log(k))+(1/3)*d(log(ays))+(1/3)*d(log(l1)))

g5oil= d(log(y)) -(0.1*d(log(b))+(1/3)*d(log(k))+(1/3)*d(log(ays))+(1/3)*d(log(l1))+0.086589*D(LOG(PROIL)))

g6=d(log(y)) -(0.1*d(log(b))+(1/3)*d(log(k))+(1/3)*d((ays))+(1/3)*d(log(l1)))

g6oil= d(log(y)) -(0.1*d(log(b))+(1/3)*d(log(k))+(1/3)*d((ays))+(1/3)*d(log(l1))+0.077845*D(LOG(PROIL)))

Note: *l2* is calculated as the population between age 14 and 65 minus the labour force, *l1*.

The first eight of these are based on equation (1'') using public capital and education labour flows with increasing returns to scale. The next four are based on equation (1) not using public capital but rather human capital, approximated by average years of schooling, *ays*, and constant returns to scale; the last two of these four named *g4* use decreasing marginal products of average years of schooling, *d(log(ays))*, whereas the previous two named *g3* follow the Mincer approach of Barro and Lee (2013) with no decrease in the marginal product of *ays*. The last four equations named *g5* and *g6* combine public capital with average years of schooling first using decreasing returns in *log(ays)* and then constant returns using *ays*. If Pritchett's argument is empirically relevant for Trinidad and Tobago the first eight equations with name variations of *g1* and *g2* containing unadjusted public capital *b* should have a lower total factor productivity growth rate than the next four named *g3* and *g4 without public capital b*, and the last four with *b* terms should have a lower TFP growth than the previous four without *B* terms, but possibly only because we have increasing returns in it through an additional argument. In all versions, physical and human capital variables as well as labour are assumed to have an elasticity of production of *1/3*. TFP growth rates with names starting with *g1*, *g5* and *g6* use an elasticity of production for public capital of *0.1* and those starting with names *g2* use *0.2* for public capital.[34] In the equations with 'lag' in the name we assume that public capital and time in education have an effect only five years later. Whenever we have calculated a TFP growth rate, we regress it on the growth rate of the oil price and add the latter multiplied by its regression coefficient to the accounting equation, leading to the equations with 'oil' in the name. The results are summarized in

Table A2	**Results of growth rate accounting**							
	G1	G1L5	G1L5OIL	G1OIL	G2	G2L5	G2L5OIL	G2OIL
Mean	-0.00132	-0.00856	-0.00840	-0.00089	-0.00533	-0.01334	-0.01317	-0.00493
Median	0.00976	0.00126	0.00108	0.00956	0.00698	-0.00156	-0.00363	0.00655
Maximum	0.111	0.100	0.109	0.120	0.112	0.099	0.109	0.120
Minimum	-0.135	-0.135	-0.123	-0.124	-0.145	-0.142	-0.129	-0.134
Std. Dev.	0.063	0.066	0.061	0.060	0.065	0.067	0.063	0.062
Skewness	-0.279	-0.181	-0.021	-0.134	-0.287	-0.164	0.022	-0.176
Kurtosis	2.153	1.917	2.262	2.372	2.184	1.881	2.221	2.423
Jarque-Bera	1.498	1.630	0.683	0.679	1.451	1.699	0.762	0.667
Probability	0.473	0.443	0.711	0.712	0.484	0.428	0.683	0.716
Observations	35	30	30	35	35	30	30	35
	G3	G3OIL	G4	G4OIL	G5	G5OIL	G06	G06OIL
Mean	-0.022	-0.021	0.003	0.003	-0.0014	-0.0010	-0.0258	-0.0254
Median	-0.018	-0.016	0.003	0.007	0.0002	0.0072	-0.0227	-0.0179
Maximum	0.076	0.084	0.105	0.114	0.106	0.114	0.077	0.084
Minimum	-0.140	-0.128	-0.124	-0.112	-0.133	-0.123	-0.145	-0.139
Std. Dev.	0.059	0.056	0.061	0.058	0.062	0.059	0.060	0.058
Skewness	-0.312	-0.234	-0.320	-0.181	-0.335	-0.230	-0.325	-0.275
Kurtosis	2.139	2.421	2.133	2.379	2.143	2.412	2.143	2.445
Jarque-Bera	1.651	0.808	1.696	0.754	-0.051	-0.036	1.68544	0.88852
Probability	0.438	0.668	0.428	0.686	0.131	0.119	0.43054	0.6413
Observations	35	35	35	35	35	35	35	35

Source: authors' calculations.

[34] Recent growth accounting literature does not use the log of public capital but rather the non-log level in a Bayesian factor analysis. The estimated coefficient then is not an elasticity of production but rather a rate of return to a change in units measured in terms of a weighted sum of standard deviations. Bresson et al. (2016) find values in the order of magnitude of 0.4 and 0.6 for infrastructure.

Table A2. The first eight columns starting with names *g1* and *g2* show slightly negative means of TFP growth rate and mostly slightly positive medians values.[35] The combinations with lags and an elasticity of production of *0.2* for capital make it more negative; the latter effect is about *0.0044*. However, when dropping public capital and going to the Mincer regressions of Barro and Lee using only private capital, the TFP growth rates become more negative, not less as one would expect if the overvaluation argument of Pritchett would apply to Trinidad and Tobago. This does partly come from taking out *L2* in addition to *B* terms because *L2* is falling since 1990; putting it in, increases TFP growth and taking it out decreases TFP growth. The term *0.1(d(log(B)) + (1/3)d(log(L2))* is also falling since 1976 because *d(log(B))* is falling from 1979 to 1988 and roughly constant afterwards. This latter fact again indicates that growth of public capital is not overstated.[36] Replacing *L2* by *ays* yields the last four equations. *G3* and *g6* should be compared because they use constant returns of *ays* and *g4* and *g5* should be compared because they use *log(ays)*. Again the difference of the means is only *-.004* from bringing in the B terms and increasing returns to scale by measure *0.1*, the assumed elasticity of production for *B*. It is hard to see an indication of overvaluation of the public capital stock for Trinidad and Tobago rather than increasing returns from adding a factor.[37] After all, the lowest TFP growth rates come from Barro-Lee type regressions with only private capital and not from those with *B* terms included.

[35] Negative growth rates of TFP may stems from shifting comparative advantage when specialization goes from more to less productive sectors. The success of the Asian NICs has brought little competition to the OECD countries but rather much to African and Latin American countries. In the latter this may therefore reduce TFP if shifting comparative advantage reduces the more productive sectors.

[36] The regression version of this is that *dlogB = 0.005348+ 0.831145dlogB(-1)* with p-value of 0.09 and 0.0000. As there is no trend the growth rate converges to *0.005348/(1-0.831145)= 0.03167*, which is lower than that of the non-oil sectors in the economy.

[37] What increases TFP growth rates is the change from differences in average years of schooling to its log, decreasing marginal productivity as supported by evidence of Földvári and van Leeuwen (2009). Estimates of elasticity of production of capital implicitly include the fact that capital has a normal degree of capital utilization of about 0.9. The minimum and maximum values of Table A2 indicate that during the business cycle the degree of utilizations may go up by about 7.5-12 per cent and down by 11-14.5 per cent taking zero TFP growth as normal. Standard deviations are about half of these extreme values.

Appendix matrices of the VECM (not for publication)

Error Correction model with dependent variables

D(LOG(CPC)) D(LOG(K)) D(LOG(B)) D(LOG(P)) D(LOG(AYS)) D(LOG(S*(1-TAU))) D(LOG(TAU)) D(LOG(LF)) D(LOG(POP))

The first eight blocks of lines represent the transposed matrix A′ of adjustment coefficients with standard errors and t-values. The next nine blocks of lines represent the coefficients B′ of the first differenced terms with standard errors and t-values. The last four blocks of lines represent the matrix of coefficients for the exogenous variables with standard errors and t-values.

CointEq1	0.834970	-0.069396	0.060216	-0.772436	-0.002937	6.562442	-0.270216	-0.022125	-0.131342
	(0.32280)	(0.10531)	(0.07249)	(0.96366)	(0.00321)	(6.00539)	(2.59823)	(0.04582)	(0.02307)
	[2.58665]	[-0.65897]	[0.83069]	[-0.80157]	[-0.91606]	[1.09276]	[-0.10400]	[-0.48284]	[-5.69277]
CointEq2	1.069535	-0.193170	0.127528	-0.860955	-0.003988	1.834476	1.958602	-0.049057	0.034923
	(0.34611)	(0.11291)	(0.07772)	(1.03324)	(0.00344)	(6.43905)	(2.78585)	(0.04913)	(0.02474)
	[3.09017]	[-1.71076]	[1.64077]	[-0.83325]	[-1.16001]	[0.28490]	[0.70305]	[-0.99845]	[1.41172]
CointEq3	-1.777684	0.185676	-0.207111	1.608168	0.007052	-5.222977	-1.099835	0.088623	0.032104
	(0.40031)	(0.13060)	(0.08990)	(1.19506)	(0.00398)	(7.44747)	(3.22215)	(0.05683)	(0.02861)
	[-4.44073]	[1.42173]	[-2.30387]	[1.34568]	[1.77342]	[-0.70131]	[-0.34134]	[1.55952]	[1.12206]
CointEq4	2.503313	-0.159978	0.184053	-3.057394	-0.009166	21.17337	-0.645510	-0.048331	-0.375286
	(0.94907)	(0.30962)	(0.21313)	(2.83327)	(0.00943)	(17.6566)	(7.63911)	(0.13473)	(0.06783)
	[2.63765]	[-0.51668]	[0.86357]	[-1.07911]	[-0.97222]	[1.19918]	[-0.08450]	[-0.35873]	[-5.53246]
CointEq5	4.169764	1.020736	1.157339	-0.346931	-0.063459	159.0736	12.65032	0.239493	0.101880
	(1.77400)	(0.57875)	(0.39838)	(5.29594)	(0.01762)	(33.0037)	(14.2790)	(0.25183)	(0.12679)
	[2.35049]	[1.76369]	[2.90510]	[-0.06551]	[-3.60102]	[4.81988]	[0.88594]	[0.95100]	[0.80351]
CointEq6	-0.506716	0.025314	-0.017703	0.562261	0.002851	-3.622281	-0.166224	0.012634	0.040316
	(0.11677)	(0.03809)	(0.02622)	(0.34858)	(0.00116)	(2.17234)	(0.93986)	(0.01658)	(0.00835)
	[-4.33956]	[0.66452]	[-0.67511]	[1.61298]	[2.45785]	[-1.66746]	[-0.17686]	[0.76218]	[4.83068]
CointEq7	-1.500928	0.159581	-0.120411	1.418605	0.006388	-4.673605	-1.850861	0.057622	0.026465
	(0.32312)	(0.10541)	(0.07256)	(0.96461)	(0.00321)	(6.01135)	(2.60081)	(0.04587)	(0.02309)
	[-4.64512]	[1.51384]	[-1.65943]	[1.47065]	[1.99015]	[-0.77746]	[-0.71165]	[1.25623]	[1.14593]
CointEq8	11.35580	-0.818137	1.076832	-9.709909	-0.070476	78.99988	-2.876910	-0.703133	-1.992781

	(5.00324)	(1.63226)	(1.12356)	(14.9362)	(0.04970)	(93.0807)	(40.2713)	(0.71025)	(0.35760)
	[2.26969]	[-0.50123]	[0.95841]	[-0.65009]	[-1.41801]	[0.84872]	[-0.07144]	[-0.98998]	[-5.57265]
D(LOG(CPC(-1)))									
	-0.520125	-0.006341	-0.004756	0.213161	-0.001638	-3.696410	1.446222	-0.011115	0.020615
	(0.13868)	(0.04524)	(0.03114)	(0.41400)	(0.00138)	(2.58000)	(1.11624)	(0.01969)	(0.00991)
	[-3.75057]	[-0.14016]	[-0.15272]	[0.51488]	[-1.18901]	[-1.43272]	[1.29562]	[-0.56461]	[2.07985]
D(LOG(K(-1)))									
	0.939888	-0.122320	-0.173102	-1.780338	-0.001733	-8.269220	-0.557163	0.098539	-0.011444
	(0.57833)	(0.18867)	(0.12987)	(1.72649)	(0.00574)	(10.7593)	(4.65499)	(0.08210)	(0.04134)
	[1.62518]	[-0.64832]	[-1.33285]	[-1.03119]	[-0.30173]	[-0.76857]	[-0.11969]	[1.20026]	[-0.27687]
D(LOG(B(-1)))									
	0.864048	-0.007359	0.047498	-1.305927	-0.015760	-10.67953	3.448738	0.078793	0.036778
	(0.79114)	(0.25810)	(0.17766)	(2.36179)	(0.00786)	(14.7184)	(6.36790)	(0.11231)	(0.05655)
	[1.09216]	[-0.02851]	[0.26735]	[-0.55294]	[-2.00541]	[-0.72559]	[0.54158]	[0.70158]	[0.65041]
D(LOG(P(-1)))									
	0.083881	-0.017265	-0.020050	0.401227	0.001411	-0.661130	0.172537	-0.011437	-0.003716
	(0.05809)	(0.01895)	(0.01304)	(0.17341)	(0.00058)	(1.08065)	(0.46754)	(0.00825)	(0.00415)
	[1.44407]	[-0.91104]	[-1.53705]	[2.31378]	[2.44562]	[-0.61179]	[0.36903]	[-1.38699]	[-0.89510]
D(LOG(AYS(-1)))									
	-30.49415	1.136866	-3.647307	73.04006	1.269036	-751.2142	-44.37708	-0.653724	-0.592829
	(10.1560)	(3.31331)	(2.28071)	(30.3189)	(0.10089)	(188.944)	(81.7466)	(1.44173)	(0.72589)
	[-3.00256]	[0.34312]	[-1.59920]	[2.40906]	[12.5787]	[-3.97586]	[-0.54286]	[-0.45343]	[-0.81669]
D(LOG(S(-1)*(1-TAU(-1))))									
	0.038698	-0.006976	0.001531	-0.033898	-0.000300	0.072117	-0.094039	0.000725	-0.000310
	(0.01353)	(0.00441)	(0.00304)	(0.04038)	(0.00013)	(0.25163)	(0.10887)	(0.00192)	(0.00097)
	[2.86106]	[-1.58083]	[0.50412]	[-0.83951]	[-2.23587]	[0.28660]	[-0.86379]	[0.37759]	[-0.32091]
D(LOG(TAU(-1)))									
	-0.044339	-0.001150	-0.001780	-0.048853	-0.000314	-0.272064	0.455455	0.010472	0.003374
	(0.05330)	(0.01739)	(0.01197)	(0.15911)	(0.00053)	(0.99157)	(0.42900)	(0.00757)	(0.00381)

	[-0.83190]	[-0.06614]	[-0.14876]	[-0.30703]	[-0.59300]	[-0.27438]	[1.06166]	[1.38404]	[0.88579]
D(LOG(LF(-1)))									
	4.103278	-0.338346	0.554973	-10.96379	-0.048534	42.81824	4.902811	0.445095	0.082664
	(1.70220)	(0.55533)	(0.38226)	(5.08161)	(0.01691)	(31.6680)	(13.7011)	(0.24164)	(0.12166)
	[2.41057]	[-0.60927]	[1.45183]	[-2.15754]	[-2.87024]	[1.35210]	[0.35784]	[1.84197]	[0.67945]
D(LOG(POP(-1)))									
	-2.654279	0.649500	0.293525	14.66662	0.071717	0.100717	-6.457579	0.063721	0.279859
	(1.99954)	(0.65233)	(0.44903)	(5.96926)	(0.01986)	(37.1997)	(16.0945)	(0.28385)	(0.14291)
	[-1.32744]	[0.99566]	[0.65368]	[2.45702]	[3.61059]	[0.00271]	[-0.40123]	[0.22449]	[1.95822]
C	0.293901	0.053238	0.120888	-0.924506	-0.003195	11.69289	0.475847	0.005633	0.018521
	(0.17120)	(0.05585)	(0.03845)	(0.51109)	(0.00170)	(3.18506)	(1.37802)	(0.02430)	(0.01224)
	[1.71669]	[0.95318]	[3.14432]	[-1.80888]	[-1.87854]	[3.67116]	[0.34531]	[0.23177]	[1.51359]
@TREND(60)									
	-0.002719	-0.001795	-0.002024	0.013611	1.95E-05	-0.148686	-0.002765	0.000398	-0.000410
	(0.00278)	(0.00091)	(0.00062)	(0.00829)	(2.8E-05)	(0.05166)	(0.02235)	(0.00039)	(0.00020)
	[-0.97922]	[-1.98116]	[-3.24607]	[1.64201]	[0.70629]	[-2.87840]	[-0.12371]	[1.00950]	[-2.06416]
@TREND*D(LOG(Z))									
	0.042405	0.017913	-0.004672	-0.039268	0.000773	0.328520	-0.127896	-0.004919	0.000695
	(0.03244)	(0.01058)	(0.00728)	(0.09683)	(0.00032)	(0.60345)	(0.26108)	(0.00460)	(0.00232)
	[1.30735]	[1.69276]	[-0.64138]	[-0.40552]	[2.39864]	[0.54441]	[-0.48987]	[-1.06824]	[0.29990]
@TREND*D(LOG(PROIL))									
	-0.000238	7.09E-05	1.03E-05	0.008852	-1.42E-06	-0.013850	0.004053	0.000116	4.07E-06
	(0.00121)	(0.00040)	(0.00027)	(0.00362)	(1.2E-05)	(0.02253)	(0.00975)	(0.00017)	(8.7E-05)
	[-0.19659]	[0.17945]	[0.03781]	[2.44806]	[-0.11817]	[-0.61466]	[0.41579]	[0.67397]	[0.04697]

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