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RESOURCE BOOM, PRODUCTIVITY GROWTH AND REAL EXCHANGE RATE DYNAMICS
- A dynamic general equilibrium analysis of South Africa

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RESOURCE BOOM, PRODUCTIVITY GROWTH AND REAL EXCHANGE RATE DYNAMICS
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Abstract

We study the impact of a natural resource boom on structural change and real exchange rate dynamics, taking into account the indirect effect via relative sectoral productivity changes. Our contribution relative to the Dutch disease literature is threefold. First, the productivity specification is extended from simple learning by doing to include trade barriers and technology gap dynamics, consistent with the modern understanding of productivity growth. Second, we offer a dynamic general equilibrium model with imperfect substitution between domestic and foreign goods. Third, the model is applied to South Africa and analyzes the macroeconomic impact of the gold price increase in the 1970s. Political pressure for rapid domestic spending after a surge in resource rents tends to generate myopic government behavior with unsustainable high consumption spending. Such fiscal response to higher resource income is captured by the model specification. Numerical simulations show how the resource boom can help explain the structural change and real exchange rate path observed in South Africa. Due to productivity effects the initial real appreciation is followed by gradual depreciation of the real exchange rate.

JEL no: O33, O41, O55, Q33.

Keywords: gold price boom, Dutch disease, trade barriers, fiscal response, deindustrialization.

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1. Introduction

The existing Dutch disease literature models learning by doing as the driving force of productivity growth. In an early contribution van Wijnbergen (1984) relates productivity growth to learning by doing in tradables, and investigates the impact of a resource boom in a two-period model. The demand-driven real exchange rate appreciation in period 1 is followed by real depreciation in the second period due to productivity effects. Torvik (2001) finds similar results in a more general setting. We offer a dynamic general equilibrium analysis of higher resource income. Our contribution to the literature is threefold. First, the productivity specification is consistent with the modern understanding of productivity growth related to trade barriers and technology gap dynamics. Introducing technology transfer as a source of productivity growth strengthens the productivity effect of a resource boom, with further implications for real exchange rate dynamics and structural change. Second, we model imperfect substitution between domestic and foreign goods, which endogenizes the tradable price and affects the real exchange rate dynamics. The effect of higher elasticity of substitution is worked out in the paper. Third, the model is applied to South Africa and analyzes the macroeconomic impact of the gold price increase in the 1970s.

Economy-wide modeling of productivity growth in developing countries often takes as a starting point the catching-up advantage of backwardness called the Veblen-Gerschenkron-effect. The mechanism was first formalized by Nelson and Phelps (1966). They assume exogenous growth of a best practice world technology frontier, and productivity growth in the backward country responds to the productivity distance to best practice. All countries can benefit from world technology frontier growth, albeit in different degrees and speeds, and dependent on the initial conditions. A modern restatement is offered by Parente and Prescott (1994) introducing the concept barriers to technology adoption. Nelson and Phelps (1966) concentrate on human capital as barrier, while the barriers as understood by Parente and Prescott (1994) are investment regulations. We focus on the broader role of international barriers as suggested in the literature of productivity spillovers and formulated by Grossman and Helpman (1991). Recent contributions by Klenow and Rodriguez-Clare (2005) and Parente and Prescott (2005) formulate the barrier model of economic growth based on the importance of international technology spillovers. Aghion and Howitt (2005) show how the catching-up can be integrated into a Schumpeterian growth model clarifying the determination of innovation and adoption.

A broad empirical literature has addressed the sources of productivity growth, and documents the importance of international spillovers through trade. In a study of 77 developing countries, Coe et al. (1997) conclude that a developing country can boost its productivity by importing a larger variety of intermediate products and capital equipment embodying foreign knowledge. Several studies indicate the importance of both openness and domestic factors for productivity growth in South Africa. The IMF study of Jonsson and Subramanian (2001) is the most enthusiastic about the productivity effect of an open economy. Harding and Rattsø (2005) address the endogeneity problem of openness and concentrate on tariff measures. In a panel analysis of 28 manufacturing sectors during 1970-2003 they document the importance of trade barriers to South African productivity growth. Fedderke (2002a) puts more emphasis to domestic factors, and identifies important productivity effects of R&D and the ratio of skilled to unskilled labor.

Recent surveys of the long-run determinants of the real exchange rate are given by Froot and Rogoff (1995) and Rogoff (1996). Commodity prices, sectoral productivity differentials, government spending, interest rate differentials and net foreign assets are typically found to affect the real exchange rate dynamics. Cashin et al. (2002) analyze the impact of commodity prices on the real exchange rate for 58 commodity-exporting countries over the period 1980-2003. They document a significant long-run relationship between commodity prices and the real exchange rate for about 40% of the countries. In a study of Australia, Canada and New Zealand, Chen and Rogoff (2002) find a strong effect of commodity prices on the real exchange rates. MacDonald and Ricci (2002) study the impact of relative productivity between sectors on the real exchange rate in a model with imperfect substitution of tradable goods. The analysis covers 10 OECD countries during 1970-92, and finds that relative productivity affects the real exchange rate both directly via the tradable price and indirectly via wages. MacDonald and Ricci (2003) offer an empirical analysis of the determinants of the South African real exchange rate during 1970-2002. The results indicate that the development in commodity prices (where the gold price accounts for more than 60%) is the most important variable explaining the real exchange rate path. In addition, relative productivity, government spending, relative real interest rate and the degree of openness affect the real exchange rate dynamics. Similar results for South Africa are documented by Aron et al. (2000).

The dynamic general equilibrium model separates between a tradable industrial sector[1], nontradable services and a pure exporting mining sector (which is modeled as an enclave). We model imperfect substitution between domestic and foreign industrial goods through an Armington composite system. As discussed by MacDonald and Ricci (2002), imperfect substitution of tradables gives a richer understanding of the real exchange rate dynamics, since the tradable price is endogenously determined. Consistent with recent modeling of productivity dynamics we combine learning by doing effects with technology adoption and trade barriers. Other Ramsey growth models with endogenous productivity dynamics include, among others, Diao et al. (2005, 2006) and Stokke (2004). Compared to these analyses the present paper focuses on the impact of a resource boom on real exchange rate dynamics and structural change. Rowthorn and Ramaswamy (1999) show that the observed deindustrialization in advanced countries is mainly due to higher productivity growth in industry together with changing composition of demand. To capture the structural adjustment observed in South Africa we control for these effects in the model specification. First, as discussed above, we include endogenous productivity dynamics at the sectoral level. Second, we apply a Stone-Geary demand system with non-homothetic preferences, where the income elasticity is relatively higher for nontradable goods. As income increases, demand is gradually shifted towards more services at the cost of industrial goods.

The impact of a resource boom on structural change and the real exchange rate depends on how the new income is allocated over time. In a normative analysis with endogenous flow of resource income Matsen and Torvik (2005) discuss the optimal spending path, and highlight the importance of a fiscal rule in the resource wealth management. There are both successes and failures among resource-rich economies, and according to the data documented by Matsen and Torvik countries that have escaped the resource curse typically have higher savings rates relative to the resource income. Røed Larsen (2003) shows that Norway has avoided the resource curse during 25 years due to good institutions and well-designed public management of the resource wealth. But as discussed by Gelb (1988) higher income generates political pressure to increase government spending, and may give Dutch disease effects (especially in countries with week institutions). In his empirical analysis of six oil-exporting developing countries, oil windfalls led to inefficient investments and unsustainable high consumption levels. This mechanism is of relevance to South Africa, where the gold price

[1] Agriculture is included in the tradable sector, and accounts for about 4% of GDP in 1998.

boom was followed by rapid increase in public consumption spending (documented in section 2). To capture the macroeconomic effects of higher gold price the model framework must take into account the fiscal response to the resource boom. In an open economy Ramsey model with perfect capital market and intertemporal optimization the impact of a surge in resource rents is smoothed over time since the new income can be invested in international assets. This might serve as a good description of the Norwegian experience, but contradicts the observed response to the gold price increase in South Africa. To capture the fiscal response to the resource boom we treat the mining sector as public, and assume myopic government behavior combined with balanced public budget giving instant use of the resource income. The public consumption path generated by the model is broadly consistent with the observed increase in public spending in South Africa since the mid 70s[2].

The development in the gold price during 1963-2003 is calibrated and used to study the impact of higher resource income on the South African economy. A reference path with constant gold price is compared to the transition path generated when the actual gold price development is taken into account. The numerical simulations show how the resource boom in the 1970s can help explain the structural change and real exchange rate path observed in South Africa in the following decades. Higher public consumption after the boom gives real exchange rate appreciation and expands nontradables at the cost of the industrial sector. There are two opposite effects on the degree of openness in the economy. The structural change away from industry contributes to lower trade-share, but at the same time some of the industrial demand shifts to foreign goods because of the increase in the domestic tradable price (following from imperfect substitution between domestic and foreign goods). In the numerical simulations the first effect dominates, and the trade-share falls with the resource boom and limits the transfer of foreign technology. Industrial productivity growth is held back due to both lower learning and less technology adoption. Productivity growth in services is also negatively affected by increased trade barriers (although to a less degree than industry), but benefits from more learning by doing. Relative industrial productivity growth declines and the change in relative productivity feeds back to affect the economic structure and the real exchange rate path. As in the theoretical analysis of Torvik (2001) the initial real appreciation

[2] In a model calibrated to Venezuela Rodriguez and Sachs (1999) assume closed capital market, so the resource income cannot be invested in international capital markets and must be spent immediately. The analysis shows that resource abundant economies may experience below steady state growth because they are living beyond their means and are overshooting their steady state level, but it does not capture structural effects of resource booms. A closed capital market may be relevant to South Africa due to international sanctions against the Apartheid regime, but we focus here on the fiscal channel to resource boom effects.

is followed by gradual depreciation of the real exchange rate. This is broadly consistent with the South African experience after the gold price boom. There are two opposite effects of lower relative productivity in industry on factor allocation between sectors. First, the industrial sector needs more labor and capital to maintain a given level of production. Second, the productivity change generates relative price effects that decrease industrial production and strengthen the structural change away from industry. In the model simulations the first effect dominates, and the productivity effect holds back the deindustrialization process.

The rest of the paper is organized as follows. Section 2 discusses the South African experience during 1963-2003. The dynamic general equilibrium model with endogenous productivity dynamics is presented in section 3, and section 4 investigates the impact of the 1970s resource boom on the real exchange rate and structural change in South Africa. Sensitivity analysis with respect to the elasticity of substitution between domestic and foreign goods is given in section 5, while section 6 offers concluding remarks.

2. The South African experience

South Africa is a mining dependent economy and the world's leading producer of gold with 55% of world production in 1980 (Jones, 2002a)[3]. Mining exports accounted for more than half of total export earnings in the 1970s and 80s and still about 40% in the 1990s (Fedderke, 2002b). Because of this high dependence on mining, and gold in particular, the development in the gold price is likely to affect the economy. The world market price of gold remained constant during the 1960s, but increased rapidly the next decade with a peak in 1980, and eventually stabilized at a new higher level almost ten times the 1960 level (illustrated in Figure 5, section 4). The price increase generated a rapid, but temporary, increase in resource rents in South Africa, as documented by Jenkins (2001), and illustrated in Figure 1 below.

Figure 1 about here

The South African mining industry is mainly private and the government has access to rents through taxation. But even if the surge in resource rents does not generate an equally rapid

[3] Lewis (2001), Jones (2002b) and Gelb (2004) offer a nice record of the recent economic history of South Africa.

increase in public revenues, political pressure may increase government spending since the country is considered to be wealthier. The empirical relevance of this mechanism is discussed by Gelb (1988) for six oil-exporting developing countries. For the case of South Africa, data from World Bank (2004) documents higher government consumption spending in the decades following the resource boom. Public consumption as share of GDP started to increase in the mid 70s from about 13% in the 1960s and early 70s to about 21% in the early 1990s before declining to about 18% post-Apartheid (Figure 2). Even though the resource boom is temporary, it is hard to reverse the increase in public expenditure, and government consumption stabilizes at a new higher level. The same period is characterized by an increasing trend in total public expenditures. The surge in total expenditures is mainly driven by public consumption, which accounts for about 50% of total expenditures in the 1960s and early 1970s compared to more than 70% since the mid 80s.

Figure 2 about here

The development in the South African real exchange rate during 1970-2002 is illustrated in Figure 3. The period is characterized by stability in the early years followed by a sharp real appreciation in the late 1970s which reaches its peak in 1985. Ignoring short run fluctuations, the post 1985 trend is a gradual depreciation of the real exchange rate.

Figure 3 about here

South Africa experienced rapid structural change after 1980 with the service sector increasing from 45% to 65% of GDP during two decades (Figure 4). Expansion of services is a common phenomenon as countries develop, but compared to the group of upper middle income countries the South African deindustrialization was much stronger. Industry represents the main part of the tradable sector, and the data documents a fall in manufacturing value added share of more than 20 percent during 1980-2003. Bell and Madula (2002) discuss the decline of the manufacturing sector, and highlight the role of the gold price boom, which generated real exchange rate appreciation and loss of competitiveness.

Figure 4 about here

3. The dynamic general equilibrium model with endogenous productivity dynamics

Most applied general equilibrium analyses in the Dutch disease literature are static, and do not capture real exchange rate dynamics or long-run structural effects of the boom (see for instance Benjamin et al., 1989, and Vos, 1998). As illustrated theoretically by Torvik (2001), productivity effects following a resource boom generate real depreciation after the initial appreciation of the real exchange rate, with further implications for factor allocation between sectors. To capture the endogenous interplay between sectoral productivity, structural change and the real exchange rate related to the South African resource boom, we offer a dynamic general equilibrium analysis. Endogenous productivity dynamics, fiscal response to higher resource income and imperfect substitution in tradables are important aspects of the model. Compared to the existing Dutch disease literature we extend the productivity specification to include trade barriers and technology gap dynamics, consistent with the modern understanding of productivity growth (Parente and Prescott, 2005, and Klenow and Rodriguez-Clare, 2005). We model a small open economy that faces a perfect capital market with the interest rate exogenously given from the world market. This means that we ignore the impact of interest rate differentials on the real exchange rate, and focus instead on the gold price, public spending and relative productivity as determinants of the South African real exchange rate. Empirical support is provided by MacDonald and Ricci (2003) and Aron et al. (2000). The rest of this section presents the most important equations of the dynamic general equilibrium model, while full documentation of the model is given in a separate appendix available from the author.

<u>The supply side</u>

The model includes three sectors: a nontradable service sector, a tradable industrial sector (which includes agriculture) and a resource (mining) sector. The industrial sector faces imperfect substitution between producing for the domestic market and the world market, and exports are endogenously determined through Constant Elasticity of Transformation (CET) functions. The resource sector exports all of its output and faces an exogenous world market price, which we later calibrate to reproduce the gold price boom in the 1970s. Sectoral value added (X) is a Cobb-Douglas function of capital (K) and labor (L):

$$X_{i,t} = A_{i,t}^{\alpha_i} L_{i,t}^{\alpha_i} K_{i,t}^{1-\alpha_i} \qquad i = M, R, S \qquad (1)$$

where subscripts M, R and S represents industry, mining and services, respectively, and t is the time period. Labor and capital are mobile between industry and services and are allocated based on marginal productivities. The resource sector is modeled as an enclave with no direct links to the rest of the economy, and employs sector specific factors of production with supply growing exogenously at the long-run rate. With this specification we ignore the resource movement effect of a resource boom and concentrate on the spending effect. This is supported by Benjamin et al. (1989) in a study of Cameron, and also seems reasonable for South Africa since the mining production is partly dependent on foreign labor (Jones, 2002a). In addition, an input-output analysis of the South African economy by Stilwell et al. (2000) finds few linkages between mining and the rest of the economy.

In industry and services labor augmenting technical progress (A) is endogenously determined from sectoral learning by doing (LBD) and technology adoption[4]. Consistent with existing specifications in the Dutch disease literature learning by doing is external and modeled through the sectoral labor shares. The early contributions by van Wijnbergen (1984) and Krugman (1987) restrict learning effects to the tradable sector. In the theoretical model of Sachs and Warner (1995) LBD is still generated in tradables, but with perfect spillovers to nontradables. The specification offered by Torvik (2001) assumes that both sectors contribute to learning, and there are imperfect spillovers between sectors. We follow Torvik (2001) and model LBD in both tradables and nontradables, but do not consider potential spillovers between domestic sectors. Technology adoption combines two elements, the distance to the world technology frontier defining the learning potential and the role of trade barriers. We apply the modified Nelson-Phelps technology gap specification suggested and empirically documented by Benhabib and Spiegel (2005). The productivity dynamics is consistent with the catching-up hypothesis, where the growth rate increases with the distance to the technological frontier. But compared to the original formulation the relationship between growth and technology gap is linear, and not exponential. This limits the advantage of backwardness and gives possible divergence in cases of high barriers to technology adoption.

Sectoral productivity growth in period t is specified as follows:

$$\frac{\dot{A}_{i,t}}{A_{i,t}} = \lambda_{1,i}\left(\frac{L_{i,t}}{L_t}\right)^{\theta_{1,i}} + \lambda_{2,i}\left(\frac{TRADE_t}{GDP_t}\right)^{\theta_{2,i}}\left(1-\frac{A_{i,t}}{A^*_{i,t}}\right) \qquad i = M, S \tag{2}$$

[4] Labor augmenting technical progress in the resource sector grows exogenously at the long-run rate.

$A_{i,t}$ and $A^*_{i,t}$ represent the domestic and frontier level of productivity, and $A_{i,t}/A^*_{i,t}$ is the technology gap. $L_{i,t}/L_t$ is the sectoral labor share and $TRADE_t/GDP_t$ aggregate trade as share of GDP (not including mining exports). Harding and Rattsø (2005) support the use of the aggregate (and not sectoral) openness measure as source of sectoral productivity growth in South Africa. The first term on the right-hand side is the contribution from learning by doing, while the second term is the technology adoption function. $\lambda_{1,i}$, $\lambda_{2,i}$, $\theta_{1,i}$ and $\theta_{2,i}$ are constant parameters. The calibration assumes $\theta_{1,i}$ and $\theta_{2,i}$ less than 1, which implies decreasing returns with respect to the two sources of productivity growth. While the impact of learning by doing is assumed to be equal across sectors ($\theta_{1,M} = \theta_{1,S}$), the industrial sector benefits relatively more from technology transfer through trade ($\theta_{2,M} > \theta_{2,S}$).

The demand side

In a general equilibrium model with perfect capital market and intertemporal optimization the impact of a resource boom is smoothed over time, since the new income can be invested in foreign assets. But as discussed in the previous section, this contradicts the South African experience, where the resource boom was followed by a rapid increase in public spending. To capture the fiscal response to higher resource income we treat the mining sector as public with the income transferred to a myopic government keeping a balanced budget. The public resource income (Y_g) comes from the factors of production in the resource sector, and is spent on a mix of industrial goods (both foreign and domestic) and services according to constant shares (αg_i):

$$Y_{g,t} = w_2 L_R + Rk_2 K_R \tag{3}$$

$$P_{i,t} \cdot G_{i,t} = \alpha g_i \cdot Y_{g,t} \qquad i = M, S \quad \text{and} \quad \sum_i \alpha g_i = 1 \tag{4}$$

where L_R and K_R are the sector-specific supply of labor and capital used in the mining sector, while w_2 and Rk_2 are the endogenous factor returns. Equation (4) represents the balanced budget constraint, where G_M and G_S are government consumption of industrial goods and services, respectively, with P_M and P_S as corresponding prices.

The representative household receives income through the primary factors employed in industry and services, while interest payments on its foreign debt are subtracted. Revenues from sales taxes and import tariffs are transferred to the household lump sum. As discussed later in this section the household is forward looking and maximizes its intertemporal utility. Within-period consumption is modeled through a Stone-Geary demand system with minimum consumption levels for each good. In this way the household has non-homothetic preferences, and the income elasticity with respect to industrial goods and services may differ. Aggregate consumption for each time period (Q_t) is defined as:

$$Q_t = cs \cdot \prod_i (C_{i,t} - \bar{C}_i)^{\alpha c_i} \tag{5}$$

where $C_{i,t}$ is consumption for each good and $\bar{C}_i$ is the minimum consumption level, which is constant over time. αc_i and cs are constant parameters. It follows that the household demand for each commodity is given by:

$$P_{i,t} \cdot (C_{i,t} - \bar{C}_i) = \alpha c_i \cdot PQ_t \cdot Q_t \tag{6}$$

In the model calibration the minimum consumption level is assumed to be relatively higher for industrial goods, which means that the income elasticity is lower here. When the income increases, demand is gradually shifted towards services at the cost of industrial goods. As illustrated by the numerical simulations the change in the consumption pattern contributes to the structural change towards services.

Since imperfect substitution between domestic and foreign goods is a common feature of most developing countries, we model import of industrial goods through an Armington composite system. As discussed by Benjamin et al. (1989), imperfect substitution between domestic and foreign goods affects the Dutch disease dynamics since the tradable price is endogenously determined and not given from the world market. The real exchange rate (*RER*) is defined as the relative price between nontradables and tradables, and is given by:

$$RER_t = \frac{P_{S,t}}{P_{M,t}} \tag{7}$$

where the tradable price (P_M) is a composite of the exogenous world market price and an endogenous domestic price. Services are not traded internationally and the price level (P_S) is determined endogenously at the domestic market.

Intertemporal dynamics

While the natural resource income is spent by a myopic public sector, the household allocates its income to consumption and savings to maximize intertemporal utility subject to a budget constraint. Assuming intertemporal elasticity of substitution equal to one we have the well-known Euler equation for optimal allocation of total private consumption expenditure over time:

$$\frac{Q_{t+1}}{Q_t}\frac{PQ_{t+1}}{PQ_t} = \frac{1+r}{1+\rho} \tag{8}$$

where Q_t is aggregate household consumption, PQ_t the aggregate price, r the world market interest rate and ρ is the positive rate of time preference. The growth in consumption depends on the interest rate, the time preference rate, and the price path. Higher interest rate or lower time preference rate motivate more savings and thereby higher consumption spending in the future.

The capital stock outside the mining sector is managed by an independent investor who chooses an investment path to maximize the present value of future profits over an infinite horizon, subject to the capital accumulation constraint. A small open economy model with exogenous interest rate and no imperfections at the capital market gives immediate adjustment of the capital stock to its steady state level if the model is calibrated to an out of steady state path. The economy takes advantage of the foreign borrowing opportunity to finance the investments to fully exploit the profit opportunities along the steady state. Introducing adjustment costs in investment is a common way of creating transition dynamics in such a model. The alternative would be to look into constraints and risks at international capital markets, which represents a future challenge for this kind of models. We follow the common practice and model adjustment costs in investment (ADJ_t), which are assumed to be a convex function of investment over existing capital stock:

$$ADJ_t = a \cdot P_{S,t} \cdot \frac{I_t^2}{K_t} \tag{9}$$

where $K_t = K_{M,t} + K_{S,t}$ is the aggregate capital stock outside mining, I_t is investment in real terms, $P_{S,t}$ the nontradable price and a is a constant parameter. Differentiating the intertemporal profit function with respect to capital gives us the well-known no-arbitrage condition:

$$rq_{t-1} = Rk_{1,t} + P_{S,t} \cdot a \cdot \left(\frac{I_t}{K_t}\right)^2 - \delta \cdot q_t + \dot{q} \tag{10}$$

The condition in (10) states that the marginal return to capital has to equal the interest payments on a perfectly substitutable asset of size q_{t-1}, where q is the shadow price of capital. The first term on right hand side, $Rk_{1,t}$, is the capital rental rate, while the second term is the derivative of capital in the adjustment cost function. The marginal return to capital also has to be adjusted by the depreciation rate, δ, and capital gain or loss, $\dot{q}$.

Investments can be financed through foreign borrowing, and the decisions about savings and investment can therefore be separated. Domestic savings and investments do not have to be equal in each period, but a long-run restriction on foreign debt exists.

Long-run equilibrium

In the long-run the productivity growth rate is given by the exogenous frontier growth rate g, and the technology gap is constant. The degree of catch-up depends on the level of barriers and the learning capacity of the economy. The long run equilibrium consequently implies a proportional relationship between A_i and A_i^*:

$$A_{i,T} = \frac{\lambda_{1,i}\left(\frac{L_{i,T}}{L_T}\right)^{\theta_{1,i}} + \lambda_{2,i}\left(\frac{TRADE_T}{GDP_T}\right)^{\theta_{2,i}} - g}{\lambda_{2,i}\left(\frac{TRADE_T}{GDP_T}\right)^{\theta_{2,i}}} \cdot A_{i,T}^* \tag{11}$$

where T represents the steady state periods. The equilibrium values of $L_{i,T}/L_T$ and $TRADE_T/GDP_T$ are constant, and the relative productivities, $A_{i,T}/A_{i,T}^*$, are determined by their values, the frontier growth rate, and the parameters. Changes in the sources of learning by doing and technology adoption generate transitional growth to a new technology gap.

Driven by technological and neoclassical convergence the long-run growth rate is exogenously given as the sum of the rate of technical progress and the labor growth rate, while transition growth is endogenous. The capital stock and the foreign debt both grow at the constant rate in the long run. This dynamics is consistent with the common understanding that differences in income and productivity levels are permanent, while differences in growth rates are transitory (Acemoglu and Ventura, 2002).

4. Resource boom, real exchange rate dynamics and structural change in South Africa

As South Africa is a resource-rich economy with mining exports (mainly gold) accounting for about half of total export earnings, shocks to the world market price of gold is likely to affect the economy. The gold price boom in the 1970s generated a rapid, but temporary, increase in resource rents (Figure 1, section 2). The mining sector is mainly private, but access to rents via taxation combined with political pressure for higher public spending after the resource boom generated higher public consumption as share of GDP from the mid 70s to the mid 90s (Figure 2, section 2). Even though the resource boom is temporary, it is hard to reverse the increase in public expenditure, and government consumption stabilizes at a higher level. We argue that the resource boom is part of the explanation behind the observed deindustrialization and real exchange rate dynamics in South Africa, and the dynamic general equilibrium model is applied to highlight the adjustment mechanisms involved.

The development in the gold price during 1963-2003 is reproduced in the model and used to study the impact of higher resource income on the South African economy. The actual and calibrated gold price path is illustrated in Figure 5 below. The model is calibrated based on a 1998 Social Accounting Matrix for South Africa, which is documented in a separate model appendix available from the author. The long-run growth rate is assumed to equal 3% (1% technical progress rate and 2% labor growth), while transition growth is endogenous. To get outside the long-run growth path we scale down the initial capital stock and productivity levels. Foreign debt and labor supply are adjusted down accordingly. To capture the impact of higher resource income on structural change and real exchange rate dynamics the baseline transition path with the calibrated gold price development is compared with a counterfactual scenario where the gold price is kept constant over time at the initial level.

Figure 5 about here

The public consumption path generated by the model is broadly consistent with the actual South African path, and initially the resource boom generates a demand-driven real exchange rate appreciation. Higher income increases the demand for both industrial goods and services, but since some of the industrial demand is directed towards foreign goods (due to imperfect substitution) the nontradable price is pushed up relatively more than the composite industrial price giving real appreciation during the boom period (Figure 6). The real appreciation of the Rand in the late 70s is observed in the data (see Figure 3, section 2), and was driven by domestic inflation. As we discuss below, the resource boom generates structural change which affects the relative productivity between domestic sectors. Over time relative industrial productivity decreases, and this feeds back on the real exchange rate dynamics. When the productivity effect is taken into account, the real exchange rate appreciation is followed by gradual depreciation (Figure 6). This is consistent with the Balassa-Samuleson hypothesis, where a reduction in industrial productivity generates depreciation of the real exchange rate. Torvik (2001) finds similar results in a theoretical analysis of higher resource income, and Torvik (2004) discusses the phasing in of oil revenues in Norway, where he documents possible real exchange rate paths consistent with long-run depreciation. Given our model specification with imperfect substitution between domestic and foreign industrial goods, the real depreciation is driven by both lower nontradable price and higher tradable price. The gradual depreciation of the real exchange rate is broadly consistent with the South African experience, and cannot be captured without taking into account the endogenous productivity effects. Section 5 discusses how the development of the real exchange rate is affected by the elasticity of substitution between domestic and foreign industrial goods.

Figure 6 about here

Following the initial real appreciation capital and labor are allocated towards the service sector at the cost of industry and gives deindustrialization. This is the spending effect of a resource boom. The development in industrial value added share is illustrated in Figure 7 (we do not include the mining sector in this calculation, so the service value added share is the mirror image of the industrial share). As seen from the figure, there is a downward trend in the value added share along the counterfactual path with constant gold price. This follows from non-homothetic preferences with higher income elasticity with respect to services. But with the resource boom the deindustrialization is strengthened. The decline in the industrial value added share during 1963-2003 is about 24%-points, while the corresponding decline along the counterfactual path equals 15%-points. The extra deindustrialization with higher resource income is supported by the empirical analysis of Palma (2005), which compares primary commodity countries to manufacturing countries and finds that the former experiences larger degree of deindustrialization. The structural shift away from industry is observed in South African data, especially after 1980 (see Figure 4, section 2). In the model the labor market adjustments are faster than in reality, and explain the immediate and earlier deindustrialization with the resource boom compared to the data.

Figure 7 about here

Sectoral productivity growth rates are affected by the resource boom via the extent of learning by doing and the barriers to technology adoption. The Dutch disease effect with deindustrialization affects sectoral labor shares and hence the productivity impact from learning. The industrial labor share declines from 0.48 in the early 70s to 0.28 at the end of the period studied. While productivity growth in industry is held back, the service sector benefits from more learning by doing. There are two opposite effects on the degree of openness in the economy. The structural change away from industry contributes to lower trade-share, but at the same time some of the industrial demand shifts to foreign goods because of the increase in the domestic tradable price. The latter effect depends on the substitution possibilities between domestic and foreign goods. With our assumption (elasticity of substitution equal to 3) the first effect dominates, and the trade-share falls with the resource boom and limits the transfer of foreign technology. Productivity growth in services and industry is negatively affected by increased trade barriers, but due to higher dependence on foreign technology the industrial productivity decline is relatively larger. Taking the learning by doing and technology transfer effects together, productivity growth in industry is negatively affected by the gold price increase, while services benefits (Figure 8).

Figure 8 about here

The change in relative productivity has two opposite effects on the allocation of production factors between sectors. First, with relatively lower productivity the industrial sector needs more labor and capital to maintain a given level of production. This tends to hold back the deindustrialization process. Second, the productivity change generates relative price effects (Figure 6) that strengthen the structural change away from industry. Higher tradable price decreases industrial demand and hence production, and shifts labor and capital towards services. As discussed in the next section, the strength of this second effect and the magnitude of the productivity shock depend on the substitution possibilities between domestic and foreign goods. In the numerical simulations the first effect dominates, and the feedback effect from relatively lower industrial productivity limits the deindustrialization process. Table 1 compares the deindustrialization effect of the resource boom with a counterfactual scenario where sectoral productivity growth rates are kept exogenous and the relative productivity is constant at the initial level. As seen from the table the reduction in the industrial value added share is 1.6 percentage points larger when the productivity effect is not taken into account, and the long-run effect on structural change is even larger (3.4 percentage points). The introduction of trade barriers to technology adoption contributes to this outcome, since higher resource income generates structural change that limits the transfer of foreign technology and strengthens the productivity effect. Based on these results applied general equilibrium models without productivity dynamics tend to exaggerate the deindustrialization effect of higher resource income. The impact of the Armington elasticity is discussed in the next section.

Table 1 about here

5. Sensitivity analysis: Elasticity of substitution between domestic and foreign goods

Using a static general equilibrium framework Benjamin et al. (1989) show that higher elasticity of substitution between domestic and foreign goods gives stronger real appreciation and more deindustrialization. In our model better substitution possibilities have two opposite effects on the real exchange rate. Consistent with the results of Benjamin et al. the demand boom following higher resource income gives less increase in the composite industrial price, which tends to strengthen the real appreciation. But even if the increase in the industrial price is lower, relatively more demand is shifted towards imported goods due to better substitution possibilities. The decline in the demand for the domestic industrial good holds back production and decreases labor demand, and consequently, decreases wages relative to the low elasticity scenario. Lower household income negatively affects the demand for industrial goods and services, and limits the increase in the nontradable price as well. This last effect dominates, and in contrast to the result by Benjamin et al. (1989), better substitution possibilities between domestic and foreign goods give weaker real appreciation after the resource boom.

Even though the real appreciation is weaker, higher elasticity of substitution implies stronger deindustrialization. This follows from lower demand for domestic industrial goods (and hence lower production) as the substitution possibilities with foreign goods improve. In the high elasticity scenario ($\sigma_m = 4$) the degree of deindustrialization is about 3 percentage points higher than in the low elasticity scenario ($\sigma_m = 1.5$), documented in Table 1 in the previous section.

How does higher elasticity of substitution affect the interplay between productivity and structural change? As discussed earlier, relatively lower industrial productivity has opposite effects on structural change. While lower productivity requires more workers to maintain a given level of production, relative price changes generate lower industrial demand and production. The strength of this second effect and the magnitude of the productivity shock depend on the elasticity of substitution between domestic and foreign industrial goods. First, for a given change in relative productivity, higher elasticity of substitution implies larger industrial production decline due to flatter demand curve. This effect means that better substitution possibilities make it more likely that the productivity effect strengthens the deindustrialization. Second, higher Armington elasticity affects relative productivity, and hence the magnitude of the productivity shock. The degree of substitution between domestic and foreign goods has two opposite effects on the industrial productivity growth rate. As discussed above, good substitution possibilities give stronger deindustrialization and hence less learning by doing in industry. But at the same time imports are kept high and stimulate productivity growth through technology transfer. In the simulations the trade effect dominates the learning effect, and industrial productivity growth increases with the elasticity of substitution between domestic and foreign goods. Productivity growth in services is stimulated by both learning by doing and technology transfer, but the decline in relative industrial productivity level following the structural change is still smaller when the elasticity is higher. This means that industrial productivity growth is stimulated relatively more from better substitution possibilities than productivity growth in the service sector. The magnitude of the productivity shock is smaller with higher elasticity of substitution and limits the industrial production decline. Hence, it is not clear whether the scale effect of lower industrial productivity is larger or smaller when the substitution possibilities improve. But as seen from Table 1 above, in the numerical simulations the last effect dominates, and higher elasticity of substitution means that the scale effect of lower industrial productivity is weaker (smaller decrease in industrial production), and it is more likely that the productivity effect limits the structural change away from industry.

The endogenous productivity specification generates gradual real depreciation after the initial appreciation of the real exchange rate. The strength of this effect is influenced by the elasticity of substitution between domestic and foreign goods. As discussed above, the magnitude of the productivity shock is smaller with better substitution possibilities, which tend to limit the real depreciation after the boom period. In addition, flatter demand curve with higher elasticity implies smaller price effect of a given productivity shock. Both effects work in the same direction, and the gradual real depreciation is weaker the higher the elasticity of substitution between domestic and foreign goods.

To sum up: First, better substitution possibilities give weaker real appreciation after the resource boom (contrary to the results in Benjamin et al., 1989), working via wage effects. Second, higher elasticity of substitution gives stronger deindustrialization after a resource boom. Third, models with exogenous productivity tend to overestimate the structural impact of a resource boom, and the degree of overestimation is larger the better the substitution possibilities between domestic and foreign goods. This last point means that the difference in the degree of deindustrialization between low and high elasticity is smaller when the productivity effect is taken into account. Hence, the analysis by Benjamin et al. (1989) tends to exaggerate the impact of higher elasticity on structural change.

6. Concluding remarks

The existing Dutch disease literature typically relates productivity improvements to learning by doing. We extend this literature by modeling productivity dynamics consistent with the barrier model of economic growth (Parente and Prescott, 2005, and Klenow and Rodriguez-Clare, 2005). Productivity growth is determined by learning effects and technology adoption, where the latter depends on the distance to the technological frontier and the extent of trade barriers. To clarify the adjustment mechanisms related to higher resource income the productivity specification is put in a dynamic general equilibrium setting. Political pressure for rapid domestic spending after a surge in resource rents tends to generate myopic government behavior with unsustainable high consumption spending. Such fiscal response to higher resource income is captured by the model specification. The model is applied to South Africa and analyzes the macroeconomic impact of the rapid gold price increase in the 1970s.

Numerical simulations show how the resource boom can help explain the structural change and real exchange rate path observed in South Africa. Increased public consumption after the boom gives real exchange rate appreciation and expands nontradables at the cost of the industrial tradable sector. There are two opposite effects on the degree of openness in the economy. The structural change away from industry contributes to lower trade-share, but at the same time some of the industrial demand shifts to foreign goods because of the increase in the domestic tradable price (following from imperfect substitution between domestic and foreign tradable goods). In the simulations the first effect dominates, and trade barriers increase with higher resource income and limit the transfer of foreign technology. Lower productivity in tradables relative to nontradables implies that the initial real appreciation is followed by gradual depreciation of the real exchange rate. This is consistent with the theoretical analysis of Torvik (2001), but the introduction of trade barriers strengthens the productivity effect of higher resource income and tends to limit the deindustrialization process.

During the period under study South Africa faced changing trade conditions due to international sanctions against the Apartheid regime, which may have affected the real exchange rate path and structural adjustments. We do not capture this mechanism with the current model specification. Our focus is rather on the effect of the gold price boom, both directly and indirectly via the relative productivity between domestic sectors. The impact of sanctions on the Dutch disease dynamics might be captured by introducing a foreign exchange constraint along the lines applied by Rattsø and Torvik (1998) in an analysis of export price shocks in Zimbabwe. The growth and distributive effects of economic sanctions are analyzed by Rattsø and Stokke (2005). The present paper is not applied to aggregate growth issues, but as discussed by Jones (2002a) the gold price boom of the 1970s might have contributed to the growth decline by raising the inflation rate and squeezing the manufacturing sector. Future research should integrate these channels of growth and investigate their relative importance.

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Figure 1. South African resource rents as share of GNP, 1970-1994. Source: Jenkins (2001).

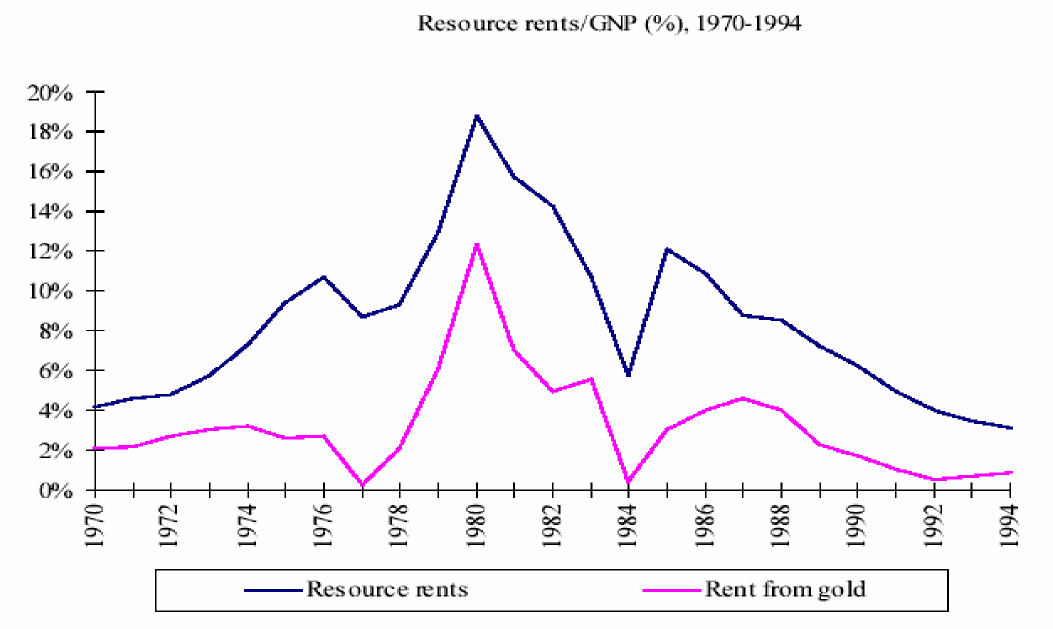

Figure 2. Government consumption spending as share of GDP in South Africa 1963-2003. Source: World Bank (2004)

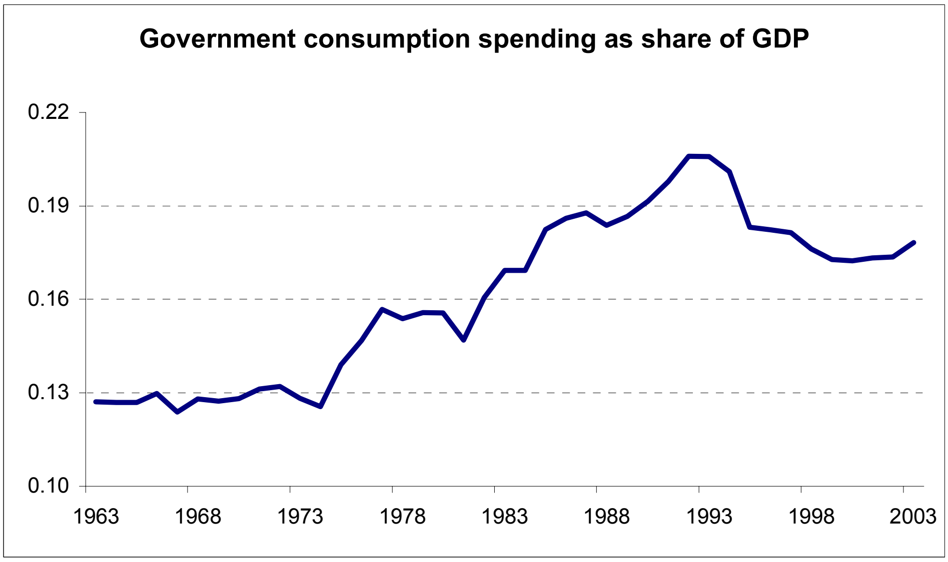

Figure 3: Real effective exchange rate, South Africa, 1970-2002
Source: MacDonald and Ricci (2003)

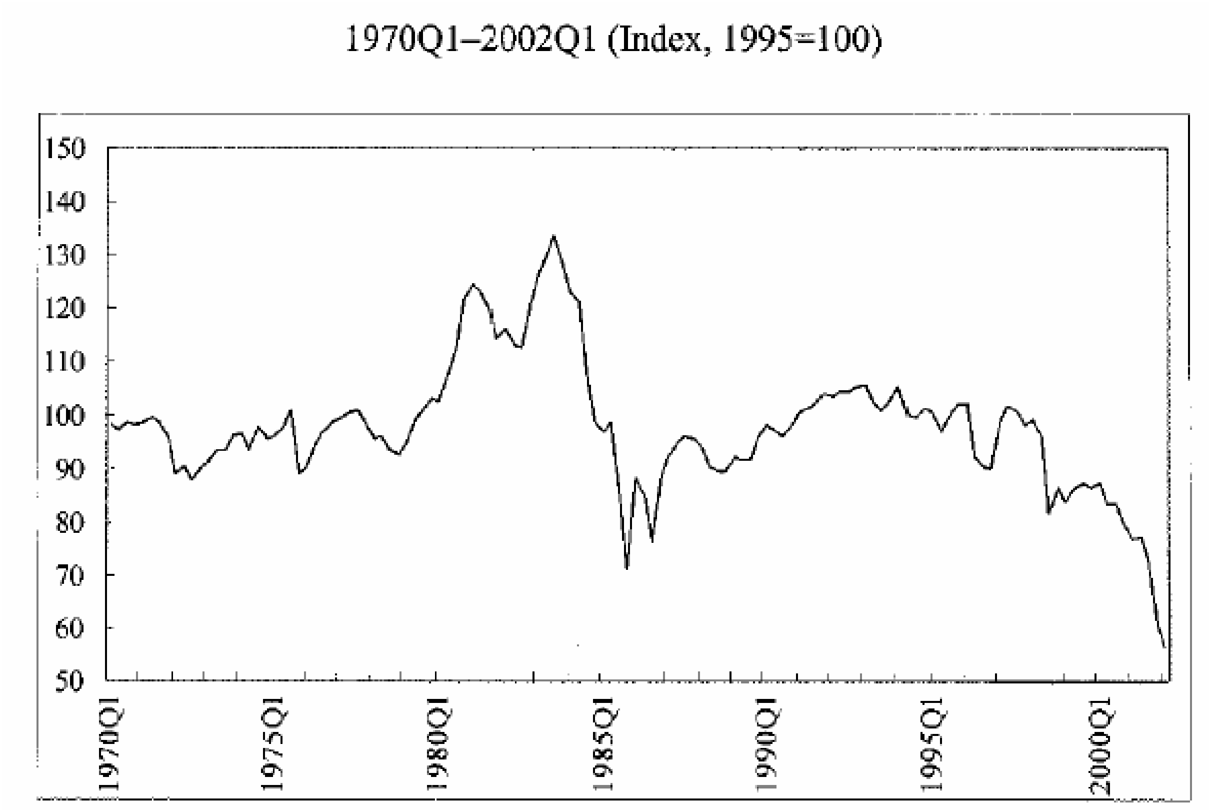

Figure 4. South African value added shares 1963-2003: Tradables and services.
Source: World Bank (2004).

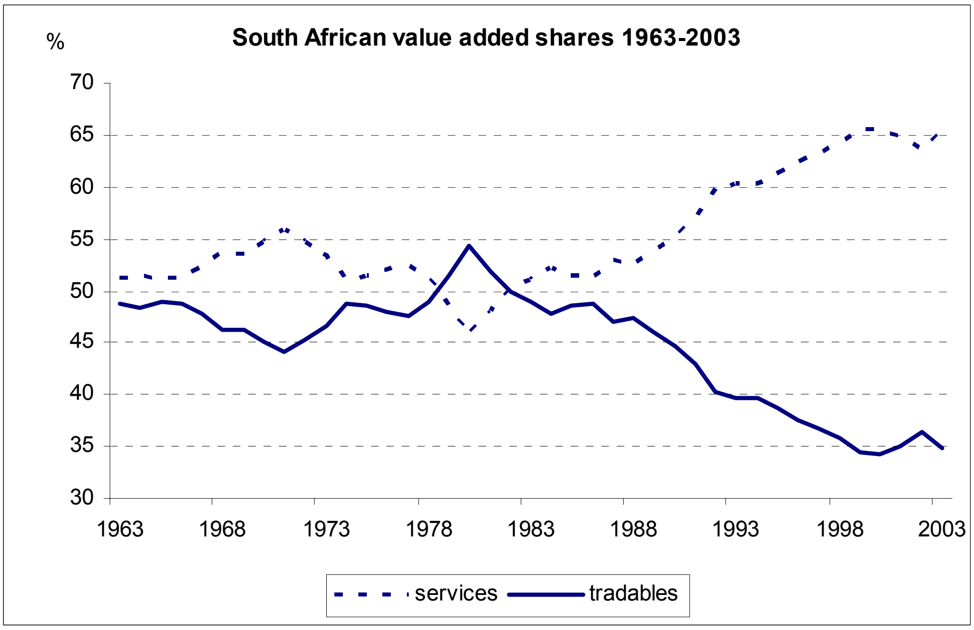

Figure 5. Calibrated gold price index vs. observed index 1963-2003.
Actual gold price index calculated based on IMF (2004).

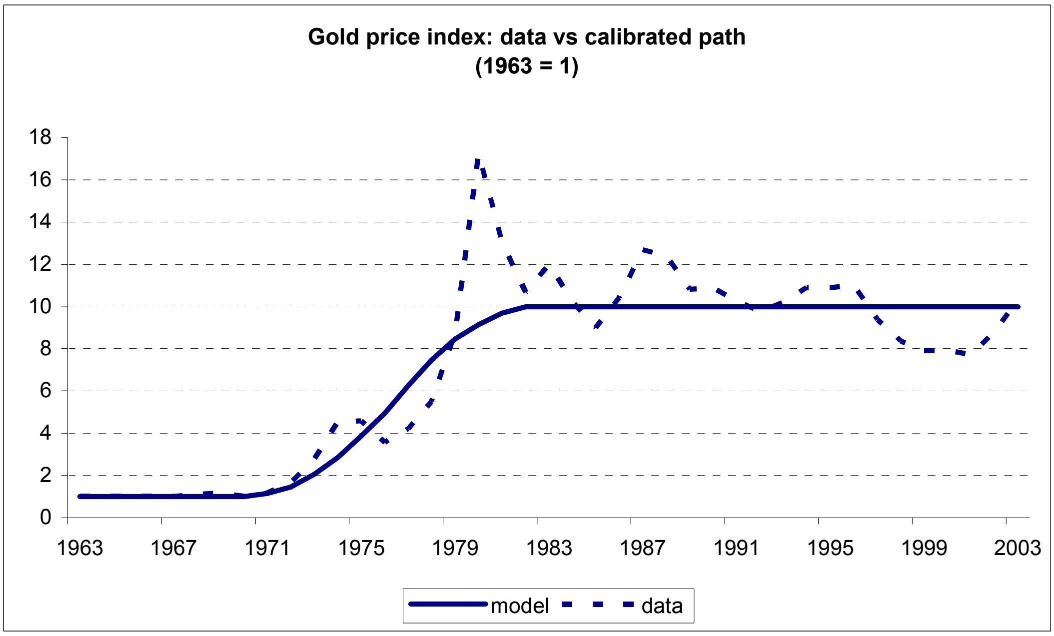

Figure 6. Effect of the resource boom on the real exchange rate development: with and without endogenous productivity effect.

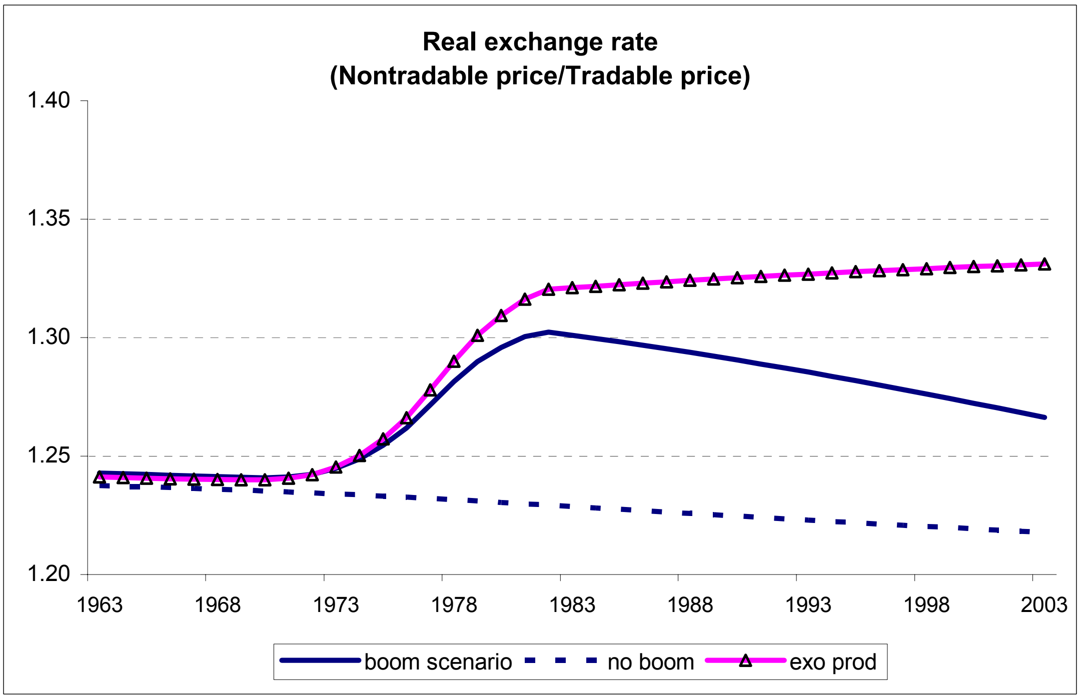

Figure 7. Effect of the resource boom on the industrial value added share.

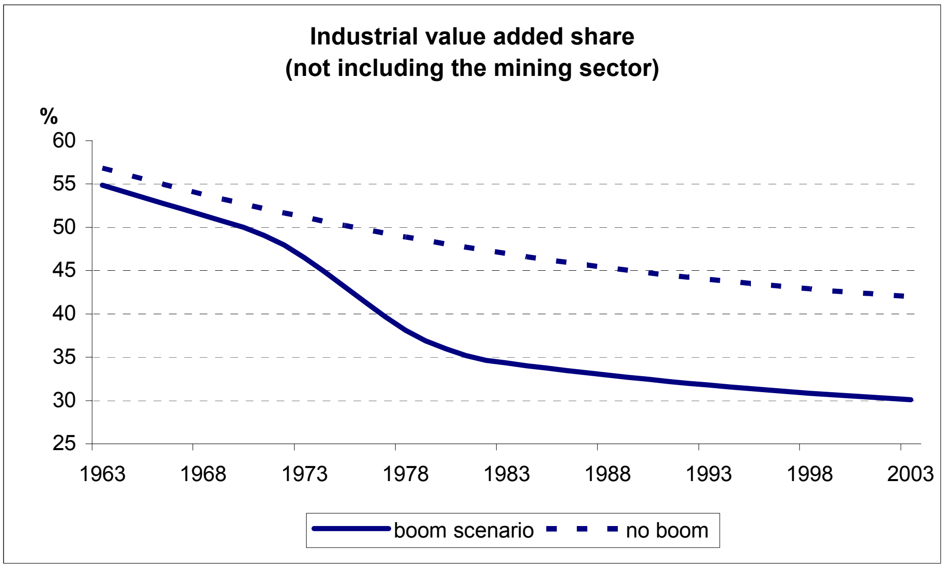

Figure 8. Productivity growth path in industry and services in the resource boom scenario

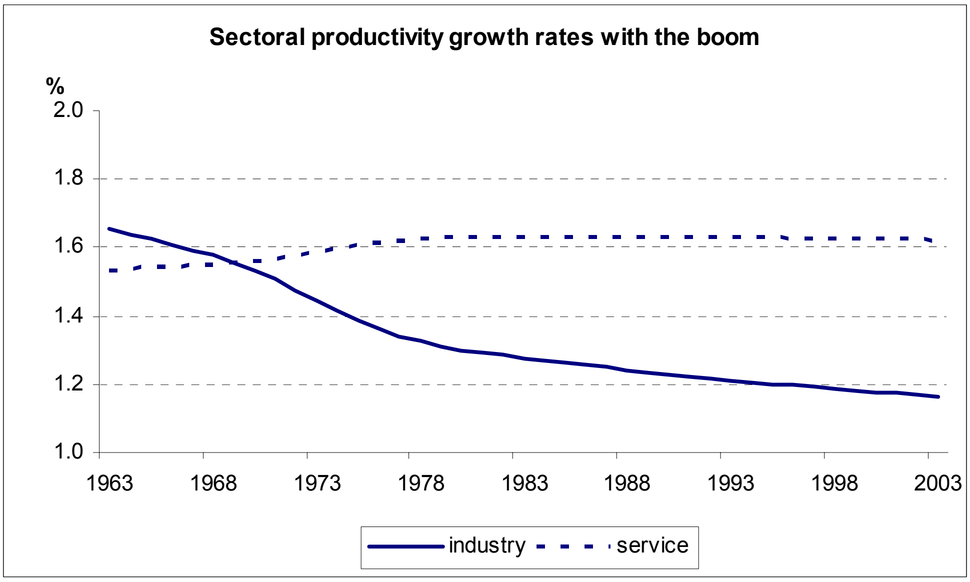

Table 1. The impact of endogenous productivity and the elasticity of substitution between domestic and foreign goods on the degree of deindustrialization

Armington elasticity	%-point deindustrialization with productivity effect		%-point deindustrialization without productivity effect		Overestimation without productivity effect	
	End of period studied (2003)	Long run (60 years)	End of period studied (2003)	Long run (60 years)	End of period studied (2003)	Long run (60 years)
$\sigma_m = 1.5$	22.9	24.7	24.0	27.0	1.1	2.3
$\sigma_m = 3$	24.8	26.3	26.4	29.7	1.6	3.4
$\sigma_m = 4$	25.6	26.9	27.8	30.9	2.2	4.0