

# Learning by doing and the Dutch disease

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## Abstract

This paper develops a model of learning by doing and the Dutch disease that extends the earlier literature in two ways. First, it is assumed that both the traded and the non-traded sector can contribute to learning. Second, it is assumed that there are learning spillovers between the sectors. It is shown that within such a model a foreign exchange gift results in a real exchange rate depreciation in the long run, due to a shift in the steady-state relative productivity between the traded and the non-traded sector. In contrast to standard models of the Dutch disease, production and productivity in both sectors may go up or down. The conditions for the different cases are worked out. © 2001 Elsevier Science B.V. All rights reserved.

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## 1. Introduction

The linkage between learning by doing (LBD) and the Dutch disease<sup>1</sup> has been the subject of at least four influential papers. Van Wijnbergen (1984a)

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<sup>1</sup> The term Dutch disease normally refers to the adverse effects on the traded sector of natural resource discoveries such as oil, gas or minerals, or of foreign aid. As many authors have pointed out, the term ‘disease’ might seem misplaced. After all, foreign exchange gifts are normally thought of as advantageous. If they were not, one could leave them untouched. Since the term seems to have survived among economists despite all the criticism, it is used here.

studies a two-period model in which tradeables productivity in the second period depends on tradeables production in the first. Krugman (1987) develops a model based on the increasing returns to scale trade theory, while Sachs and Warner (1995) employ an endogenous growth model. In addition, a recent contribution by Gylfason et al. (1997) extends the literature by studying how the Dutch disease affects exchange rate volatility, and thereby investment and productivity growth. All the models show aspects of the Dutch disease that are left out in models with exogenous productivity, but they also leave out important points.

The models find unanimously that a foreign exchange gift implies a lower level of productivity. The agreement rests upon the assumption that LBD is only generated in the traded sector. Since a foreign exchange gift decreases the size of the traded sector, productivity is reduced. In Gylfason et al. (1997) an additional channel contributes to the same result. When the Dutch disease not only implies a real exchange rate appreciation, but also increases real exchange rate volatility, the traded sector (and thus productivity growth) is further depressed because investment is reduced.

The assumption that the traded sector is the sole contributor to LBD may clearly be a realistic approximation for some countries, and equally unrealistic for others. Norway's most important exports besides oil and gas are fish and metals, while Nigeria's are cocoa and rubber. Much of the Netherlands' exports are manufactured goods. Consider Zambia and Zimbabwe, neighbouring countries that both receive significant amounts of foreign aid. Zambia basically exports metals (copper and cobalt), while a third of Zimbabwe's exports are, in fact, manufactured goods. The largest among the traded sectors in Zimbabwe is agriculture. In Norway, due to import restrictions, most of the agriculture belongs in the non-traded sector. Motivated by import-substituting industrialisation, most sub-Saharan African countries have chosen to control imports of manufactured rather than agricultural goods. The heavy import restrictions mean that the manufacturing sector in sub-Saharan Africa has the characteristics of a non-traded sector (see e.g. Davies et al., 1994). The traded and non-traded sectors differ considerably between countries. Furthermore, what must be grouped under the non-traded sector in some countries must be grouped under the traded sector in others, and vice versa. Is the approximation that LBD can only be generated in the traded sector equally true for all these countries? Most economists would probably disagree. Since the results of the earlier literature on LBD and the Dutch disease are fully dependent on an assumption which applicability differs from country to country, it should clearly be of some interest to investigate alternatives. This is the aim of the present paper. It is assumed that both the traded and the non-traded sector have endogenous productivity, that both sectors can contribute to LBD, and that there are learning spillovers between sectors. Such a model introduces some interesting new effects compared with earlier models of LBD and the Dutch disease.

First, the model has implications for real exchange rate dynamics in the event of an increased foreign exchange gift. Although the short-term response is a real exchange rate appreciation in the standard fashion, the long-term response is a real exchange rate depreciation. This is due to a shift in steady-state relative productivity between the traded and the non-traded sector. Second, the standard result in the Dutch disease literature that the output of traded goods (not experiencing a productivity boom) must fall, may be turned around. The conditions for increased or decreased long-run productivity and production in both sectors are worked out.

The paper is organised as follows: Section 2 presents the model. Static equilibrium is discussed in Section 3, which results in the dynamic model in Section 4. Section 5 then investigates the dynamics of factor allocation, relative productivity and the real exchange rate after an increased foreign exchange gift. Section 6 is devoted to growth implications, while concluding remarks are presented in Section 7.

## 2. The model

To focus attention on the new mechanisms in the model, four simplifying assumptions are made. The first is that there is no unemployment, the second that the foreign exchange inflow stemming from the sale of natural resources or foreign aid is exogenous, the third that we have balanced trade, and the fourth that labour is the only production factor. Although the four assumptions are the same as in other models of LBD with multiple goods, such as those of Krugman (1987) and Young (1991), the reasons they are imposed deserve some brief comments. The first assumption is made because it is not the intention to study temporary labour market disequilibrium in the transition from one steady state to another. For the relationship between unemployment and foreign exchange inflow, see e.g. Van Wijnbergen (1984b). The second assumption is made because it will be assumed at the outset that a country receives a foreign exchange gift, and whether the gift is from mother nature or other countries will not be discussed. Since optimal resource extraction or policies to secure foreign aid lie outside the scope of this paper, the foreign exchange gift is made exogenous. The reader may consult Dasgupta and Heal (1978) on optimal resource extraction, and Pedersen (1996) on endogenous policy formation to secure foreign aid. The assumption of balanced trade is made in order to exclude optimal foreign asset accumulation from the discussion. It may result from imperfect capital markets or policy controls. Van Wijnbergen (1984a) and Neary and Van Wijnbergen (1986) discuss the use as well as the policy implications of the assumption in models with LBD. Mansoorian (1991) discusses why a resource discovery may lead to 'excessive' borrowing, and investigates the short and long-run economic consequences in this case. For models of optimal current

account dynamics, see for example Obstfeld and Rogoff (1996). The fourth assumption has two simplifying implications. The first is that there are no capital stock dynamics, only productivity dynamics, in the different sectors. The second simplifying implication is that when taken together with the third assumption, the last assumption implies that the savings rate equals zero (since we have ruled out both financial and real investments). Consequently, consumption expenditure equals income.

Production and productivity (or human capital) in sector  $i$  at any point  $t$  in time are denoted  $X_{it}$  and  $H_{it}$ , respectively.  $i = N$  refers to the non-traded sector, and  $i = T$  to the traded sector. The total labour force is normalised to equal one, and  $\eta_t$  denotes the labour force employed in the non-traded sector at time  $t$ . The production functions in the two sectors take the following form:

$$X_{Nt} = H_{Nt}f(\eta_t), \quad f'(\eta_t) > 0, \quad f''(\eta_t) < 0, \quad (1)$$

$$X_{Tt} = H_{Tt}g(1 - \eta_t), \quad g'(1 - \eta_t) > 0, \quad g''(1 - \eta_t) < 0. \quad (2)$$

Except for endogenous productivity parameters, the model can be interpreted as the standard specific-factors model. Labour is the only intersectorally mobile factor and, at given productivity levels, there are diminishing returns to labour in each sector. The production functions are the same as in e.g. Matsuyama (1992). As usual in the endogenous growth literature with one factor of production, the productivity parameters enter with constant returns to scale. To complete the description of the supply side in this dependent economy model, it only remains to endogenise the sectoral productivities.

Productivity evolves over time according to an LBD mechanism. As in the earlier literature, the LBD is external to firms, the underlying assumption being that each firm is too small to take its own contribution to LBD into account. Two choices have to be made regarding the modelling of this mechanism. The first is which sectors contribute to learning, the second which sectors benefit from learning. With the exception of Sachs and Warner (1995), the earlier literature has the same answer to both questions: It is the traded sector that contributes to learning, and it is the traded sector that benefits from learning. Productivity in the non-traded sector is assumed to be exogenous. In other words, there are no learning spillovers between sectors. Sachs and Warner (1995) represent the opposite extreme. The assumption that LBD can only be generated in the traded sector is adopted, but a perfect spillover to the non-traded sector is assumed. The sectors have a common level of productivity by definition.<sup>2</sup>

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<sup>2</sup> Unfortunately, only a few papers have studied endogenous growth in the dependent economy model. Sachs and Warner (1995) and Gylfason et al. (1997) are the only models I am aware of that study the Dutch disease in such a model. In addition, some other authors incorporate endogenous

The assumption that LBD can only be generated in one out of the two sectors and the assumption of either perfect spillover or no spillover represent extremes that may seem unrealistic.<sup>3</sup> The assumptions of earlier literature are therefore modified in both respects in Eqs. (3) and (4) below. One unit of labour use in the non-traded sector contributes with a productivity growth rate of  $u$  in the non-traded sector. Conversely, one unit of labour use in the traded sector contributes with a productivity growth rate of  $v$  in the traded sector. It is assumed that a fraction  $\delta_T$  of the learning from employment in the traded sector spills over to the non-traded sector, and that a fraction  $\delta_N$  of the learning from employment in the non-traded sector spills over to the traded sector. The analysis is restricted to cases where the spillover effects cannot be stronger than the direct effects.

$$\frac{\dot{H}_{Nt}}{H_{Nt}} = u\eta_t + v\delta_T(1 - \eta_t), \quad 0 \leq \delta_T \leq 1, \quad (3)$$

$$\frac{\dot{H}_{Tt}}{H_{Tt}} = u\delta_N\eta_t + v(1 - \eta_t), \quad 0 \leq \delta_N \leq 1. \quad (4)$$

In these equations, Van Wijnbergen (1984a) and Krugman (1987) represent the case where  $u = \delta_T = \delta_N = 0$ , while Sachs and Warner (1995) assume that  $u = \delta_N = 0$ , and  $\delta_T = 1$ .

To allocate consumer spending on non-traded ( $C_N$ ) and traded ( $C_T$ ) goods, a utility function  $U$  with a constant elasticity of substitution  $\sigma$  between the two goods is employed:

$$U_t = \frac{\sigma}{\sigma - 1} C_{Nt}^{(\sigma-1)/\sigma} + \frac{\sigma}{\sigma - 1} C_{Tt}^{(\sigma-1)/\sigma}, \quad \sigma > 0. \quad (5)$$

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growth in the dependent economy model. Premer and Walz (1994) assume that the traded sector has endogenous productivity growth, and investigates regional specialisation, trade, and migration patterns. Rauch (1997) models a backward country that acquires all knowledge from abroad, and studies whether the economy will experience balanced or unbalanced growth. Turnovsky (1996) discusses how the equilibrium growth path in the dependent economy model depends on relative capital intensities, when traded capital is interpreted as physical capital and non-traded capital as human capital. Dinopoulos and Syropoulos (1997) introduce a non-traded good in a multi-country model, and analyse how this affects the outcome of multilateral, bilateral and unilateral schemes of trade liberalization. The Dutch disease is studied in a one sector endogenous growth model with rent-seeking in Lane and Tornell (1996), and in an agriculture/industry model in which both goods are tradeables in Matsuyama (1992). As in other models of the Dutch disease with endogenous productivity, the unambiguous result in these papers is also decreased productivity.

<sup>3</sup> This would not have been a problem if the assumptions were merely simplifying, and did not affect the qualitative results. But they do.

At any point in time, the total income measured in traded goods,  $Y_t$ , is given by the value of production in the non-traded and traded sectors, plus the value of the foreign exchange gift.  $R_t$  is the (flow of the) foreign exchange gift measured in traded sector productivity units at time  $t$ , so  $H_{Tt}R_t$  is the foreign exchange gift measured in traded goods units.<sup>4</sup> When  $P_t$  is the price of non-traded goods in terms of traded goods, i.e. the real exchange rate, total income is given by

$$Y_t = P_t X_{Nt} + X_{Tt} + H_{Tt} R_t. \quad (6)$$

It follows from the assumptions above that consumption equals income at any point in time. The demand for non-traded goods is then given by

$$C_{Nt} = \frac{Y_t}{P_t(1 + P_t^{\sigma-1})}. \quad (7)$$

### 3. Static equilibrium

At any point in time, demand must equal the supply of non-traded goods. Combining Eqs. (1), (2), (6) and (7), this yields a combination of the real exchange rate and the employment share in the non-traded sector (for given values of the foreign exchange gift and sectoral productivities) consistent with equilibrium. Defining  $\lambda_t = H_{Tt}/H_{Nt}$ , i.e. the productivity level in the traded sector relative to that in the non-traded sector, the resulting expression can be written as

$$P_t = \lambda_t^{1/\sigma} \left[ \frac{g(1 - \eta_t) + R_t}{f(\eta_t)} \right]^{1/\sigma}. \quad (8)$$

The equation is drawn as the downward sloping curve NN in Fig. 1. Assume that we start out in an equilibrium in the market for non-tradeables, and that  $\eta_t$  then increases for a given  $P_t$ . This creates an excess supply of non-traded goods. To restore equilibrium with the new labour allocation,  $P_t$  has to fall. The real exchange rate depreciation helps the market back to balance by shifting demand from traded to non-traded goods.

Another combination of the real exchange rate and the labour share in the non-traded sector is found from the labour market. Assuming full employment

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<sup>4</sup> Hence, if  $R_t$  is constant over time this implies that the real value of the foreign exchange gift grows by the same rate as productivity in the traded sector. The two obvious alternatives are to measure  $R_t$  in non-traded sector productivity units or as a fraction of income. The steady-state solution of the model is independent of this choice, and none of the qualitative results of the static model are affected. However, the analysis does depend on the assumption that the (flow of the) foreign exchange gift, in one way or another, grows over time. If the foreign exchange gift is constant over time, it will make up a smaller and smaller fraction of a growing economy, and the foreign exchange gift as a share of income will converge towards zero.

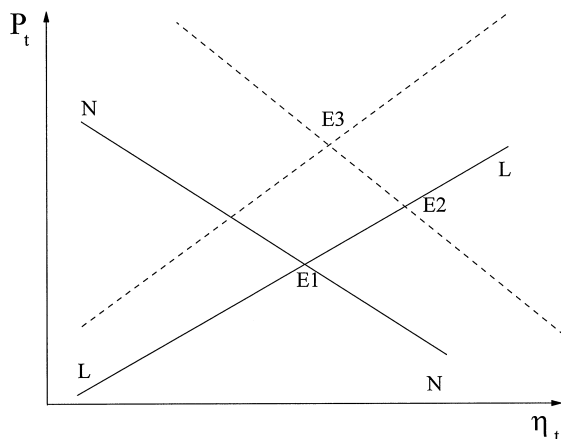


Fig. 1.

and perfect labour mobility between the two sectors, the value of the marginal productivity of labour must be equal in the non-traded and the traded sectors.<sup>5</sup> The result is

$$P_t = \lambda_t \frac{g'(1 - \eta_t)}{f'(\eta_t)}. \tag{9}$$

The equation is drawn as the upward sloping curve LL in Fig. 1. Assume that we start out in equilibrium, and that the price of non-tradeables rises so that the real exchange rate appreciates. Then, the value of the marginal productivity of labour in the non-traded sector is higher than in the traded sector. To reestablish the equality between the value of the marginal productivity of labour in the two sectors at the new real exchange rate, labour use in the non-traded sector has to increase and labour use in the traded sector has to decrease.

The equilibrium point is denoted E1 in Fig. 1. Figures similar to Fig. 1 are found in e.g. Corden and Neary (1982, Fig. 3) and Corden (1984, Fig. 1).

Now, what is often referred to as the Dutch disease can easily be studied by assuming an increase in the foreign exchange gift. In Fig. 1, the curve for balance in the market for non-traded goods shifts up when  $R_t$  increases. Demand for non-traded goods is higher, and at every level of  $\eta_t$  the real exchange rate must

<sup>5</sup>  $P_t H_{Nt} f'(\eta_t) = w$  and  $H_{Tt} g'(1 - \eta_t) = w$ , where  $w$  is the wage measured in traded goods units, and  $w$  adjusts to achieve full employment. Because of LBD this is not generally the socially optimal labour allocation. Different learning effects in the sectors are not taken into account by the firms in their hiring decisions. Therefore, the sector that contributes the most to LBD will in general employ too few, and the other sector too many.

rise to keep the market in balance. The labour market equilibrium curve is unaffected by an increased foreign exchange gift. The new static equilibrium, E2, is characterised by the two common symptoms of the Dutch disease: a real exchange rate appreciation and a larger share of the production factors employed in the non-traded sector.

For the purpose of the dynamic analysis, we also need to know how an increased productivity differential between the two sectors affects the static equilibrium. When productivity in the traded sector increases relative to that in the non-traded sector, the curve for non-traded market balance shifts up. For a given labour allocation, a higher productivity differential means that the supply of traded goods increases relative to the supply of non-traded goods. To bring the market back into balance, the real exchange rate has to appreciate, shifting the relative supply in favour of more non-traded goods. It can easily be verified that the vertical shift in the curve when  $\lambda_t$  increases is given by  $P_t/\sigma\lambda_t$ .

When  $\lambda_t$  increases, the labour market equilibrium curve shifts to the left. For a given real exchange rate, a higher productivity differential means that with the initial allocation of labour, the value of the marginal productivity of labour in the traded sector exceeds that in the non-traded sector. Hence, for a given real exchange rate,  $\eta_t$  must fall so that marginal productivity increases in the non-traded sector and decreases in the traded sector. The vertical shift in the curve when  $\lambda_t$  increases is given by  $P_t/\lambda_t$ .

The static equilibrium after the shift in relative productivity is denoted E3 in Fig. 1. The unambiguous result of an increased  $\lambda_t$  is a real exchange rate appreciation. When the relative productivity between the sectors changes, equilibrium conditions require the relative price to change in the opposite direction. The result can be regarded as a version of the Balassa–Samuelson effect: With a faster level of productivity growth in the traded than in the non-traded sector, the real exchange rate appreciates. An endogenisation of this relative productivity effect is offered later when the transitional and steady-state dynamics of the model are studied.

The employment response to increased  $\lambda_t$  is ambiguous. If  $\sigma > 1$ , the vertical shift in the LL curve is greater than the vertical shift in the NN curve. Consequently, when the elasticity of substitution exceeds one, a smaller share of the labour force is employed in the non-traded sector. If  $\sigma < 1$ , as in Fig. 1, the vertical shift in the NN curve dominates, and  $\eta_t$  increases. Two conflicting forces are at work. With the relative shift in productivity, the labour requirement in the production of traded goods has fallen compared with that in the production of non-traded goods. With unchanged consumption shares, labour must be shifted away from the traded sector and into the non-traded sector. However, since it is relatively cheaper to produce traded goods than before, consumers will substitute away from non-traded goods. This points to reduced employment in the non-traded sector, and more employment in the traded sector. If the elasticity of substitution falls short of one, the substitution effect is smaller than the effect of



the shift in labour requirements, and employment in the non-traded sector increases.<sup>6</sup> The employment response in the static model is summarised in Eq. (10):

$$\eta_t = \eta(\lambda_t, R_t), \quad \frac{d\eta_t}{d\lambda_t} < 0 \quad \text{if } \sigma > 1, \quad \frac{d\eta_t}{d\lambda_t} > 0 \quad \text{if } \sigma < 1, \quad \frac{d\eta_t}{dR_t} > 0. \quad (10)$$

#### 4. The dynamic model

The dynamic model now consists of the following three differential equations:

$$\frac{\dot{H}_{Nt}}{H_{Nt}} = u\eta(\lambda_t, R_t) + v\delta_T[1 - \eta(\lambda_t, R_t)], \quad (11)$$

$$\frac{\dot{H}_{Tt}}{H_{Tt}} = u\delta_N\eta(\lambda_t, R_t) + v[1 - \eta(\lambda_t, R_t)], \quad (12)$$

$$\frac{\dot{\lambda}_t}{\lambda_t} = \frac{\dot{H}_{Tt}}{H_{Tt}} - \frac{\dot{H}_{Nt}}{H_{Nt}}. \quad (13)$$

The model can most easily be studied by reducing these expressions to a differential equation in relative productivity:

$$\frac{\dot{\lambda}_t}{\lambda_t} = -u(1 - \delta_N)\eta(\lambda_t, R_t) + v(1 - \delta_T)[1 - \eta(\lambda_t, R_t)]. \quad (14)$$

To check for a steady-state solution where  $\lambda_t$  remains constant over time, so that productivity growth is the same in both sectors, the stability properties of the model have to be investigated. The feedback from  $\lambda_t$  on its own growth rate is given by

$$\frac{d(\dot{\lambda}_t/\lambda_t)}{d\lambda_t} = -[u(1 - \delta_N) + v(1 - \delta_T)] \frac{d\eta(\lambda_t, R_t)}{d\lambda_t}. \quad (15)$$

Thus, it is clear from Eq. (10) that if  $\sigma > 1$  the differential equation in  $\lambda_t$  is unstable, while stability is guaranteed if  $\sigma < 1$ . These cases are discussed in turn.

<sup>6</sup> The effect of relative productivity on the non-traded labour share is

$$\frac{d\eta_t}{d\lambda_t} = \frac{(1 - \sigma)\lambda_t^{-1}}{\frac{g'(1 - \eta_t)f(\eta_t) + f'(\eta_t)[g(1 - \eta_t) + R_t]}{f(\eta_t)[g(1 - \eta_t) + R_t]} - \sigma \frac{f''(\eta_t)}{f(\eta_t)} - \sigma \frac{g''(1 - \eta_t)}{g'(1 - \eta_t)}}.$$

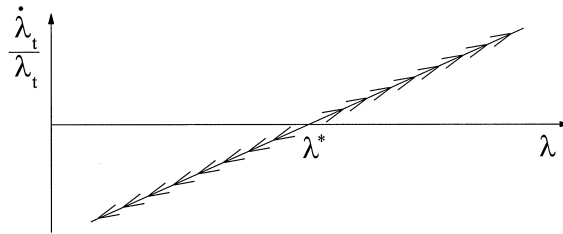


Fig. 2.

#### 4.1. Unbalanced growth

Fig. 2 shows the phase diagram when the elasticity of substitution is higher than one. The (unstable) steady-state solution for relative productivity is denoted  $\lambda^*$  in the figure. Assume that productivity in the traded sector relative to the non-traded sector is higher than  $\lambda^*$  initially. Then, since the elasticity of substitution exceeds one, the share of the workers employed in the traded sector is higher than would be the case if  $\lambda_t = \lambda^*$ . Consequently, the LBD is stronger in the traded sector than in the non-traded sector, meaning that the relative productivity gap grows even more. This results in an even higher share of the workers in the traded sector, meaning an even larger productivity gap, and so on. Over time, the economy converges towards full specialisation in traded goods. The dependent economy model is reduced to the perfectly open economy one. The asymptotic growth rate in the economy is given by  $v$ .

Assume next that  $\lambda_t < \lambda^*$  initially. Then the share of workers in the non-traded sector is higher than it would be if  $\lambda_t = \lambda^*$ , productivity grows faster in the non-traded than in the traded sector, employment and production follow suit, and the economy ends up with specialisation in non-traded goods. The dependent economy model is reduced to the closed economy one, with the asymptotic growth rate given by  $u$ .<sup>7</sup>

The models of Van Wijnbergen (1984a) and Krugman (1987) can be grouped under the heading of unbalanced growth. In these papers, unbalanced productivity growth is assumed, since non-traded sector productivity is exogenous while traded sector productivity grows.

<sup>7</sup> Note that the growth results with specialisation remain valid also when the foreign exchange gift is taken into account. With specialisation in traded goods, the foreign exchange gift grows by the rate  $v$ , which is the same as the rest of the economy. With specialisation in non-traded goods, the foreign exchange gift grows by the rate  $u\delta_N$  (which is the growth rate of traded sector productivity when only non-traded goods are produced). Since the foreign exchange gift cannot grow faster than the rest of the economy, the asymptotic growth rate is given by  $u$ .

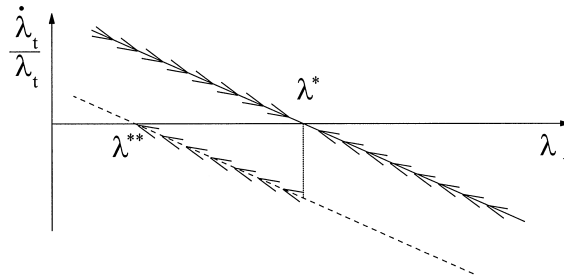


Fig. 3.

The possibility of LBD-generated unbalanced growth as shown in the model is interesting in itself. However, when the dependent economy model ends up as a one-sector model, it can be argued that a discussion of the Dutch disease has limited interest.<sup>8</sup> In the remainder of the analysis it is therefore assumed that steady-state growth is balanced. Rauch (1997) provides a discussion of balanced and unbalanced growth in a dependent economy model.

#### 4.2. *Balanced growth*

When the elasticity of substitution is less than one, the model has a stable interior solution for the productivity gap, denoted  $\lambda^*$  in Fig. 3. Assume that  $\lambda_t > \lambda^*$  initially. Since  $\sigma < 1$ , the share of the labour force in the traded sector is lower than it would be at  $\lambda_t = \lambda^*$ , because now the labour requirement effect outweighs the substitution effect. Productivity growth is then stronger in the non-traded than in the traded sector, and  $\lambda_t$  falls over time until it reaches its steady-state value  $\lambda^*$ . In the same way, if  $\lambda_t < \lambda^*$ , the allocation of employment is such that productivity in the traded sector grows faster than in the non-traded sector, until  $\lambda_t$  is back to its steady-state value. Among the earlier contributions on LBD and the Dutch disease, Sachs and Warner (1995) have balanced productivity growth. In their model growth is balanced by definition, since the relative productivity between the traded and the non-traded sector is exogenous.

When  $\lambda_t$  reaches its steady-state value  $\lambda^*$ ,  $\eta_t$  is also at its steady-state value, given by

$$\eta^* = \frac{v(1 - \delta_T)}{u(1 - \delta_N) + v(1 - \delta_T)}. \tag{16}$$

<sup>8</sup> The exception to this is when  $\lambda$  is marginally higher than  $\lambda^*$ . Then, if the foreign exchange gift remains constant, the economy will specialise in traded goods. But if the foreign exchange gift increases sufficiently, permanently or temporarily, specialisation will be in non-traded goods instead. In this way, even a temporary foreign exchange gift can influence the steady-state growth rate of the economy.

It follows immediately that the steady-state labour allocation is independent of the foreign exchange gift. It then follows from Eq. (10) that as long as  $\sigma < 1$  there is a negative relation between  $\lambda_t$  and the foreign exchange gift between steady states. To explain the intuition for this, as well as the transitional dynamics and economic consequences, the Dutch disease dynamics are investigated in the next section.

Before attention is turned to the dynamics, however, it is useful to discuss two special cases not explicitly considered so far. The first is the case where one of the indirect LBD effects is perfect. The second is the case where  $\sigma = 1$ , implying a Cobb–Douglas utility function.

Consider the case where  $\delta_T = 1$  at the same time as  $u(1 - \delta_N) > 0$ , or the case  $\delta_N = 1$  at the same time as  $v(1 - \delta_T) > 0$ . Then from Eq. (16)  $\eta^* = 0$  in the first case and  $\eta^* = 1$  in the second case. At first sight one may then think that in long-run equilibrium only traded goods are consumed in the first case and only non-traded goods in the second case. But this is not what is happening. The reason is that in this case Eq. (16) holds only asymptotically. To make the intuition clear it suffices to look at one of the cases. When  $\delta_T = 1$  at the same time as  $u(1 - \delta_N) > 0$ , it follows from Eqs. (11) and (12) that the non-traded sector will always have higher productivity growth than the traded sector.  $\lambda_t$  will have no interior stable solution, but will asymptotically converge towards zero, as can be seen from Eq. (14). Since both goods are essential to consumers when  $\sigma < 1$ , this implies that labour has to be shifted from the non-traded to the traded sector to compensate for the lower productivity growth in the latter. Asymptotically, the non-traded sector is ‘infinitely’ more productive than the traded sector, so the size of the labour force in the traded sector relative to the non-traded sector must be ‘infinite’ to keep up production relative to the non-traded sector. Asymptotically, the labour share in the non-traded sector converges to zero, but both goods are consumed. Sachs and Warner (1995) assume that  $\delta_T = 1$ , but at the same time they assume that  $u = 0$  so that  $u(1 - \delta_N) > 0$  does not hold. Then productivity growth between the sectors does not differ when indirect LBD is perfect, because when  $u = 0$  the sectors have the same productivity growth by definition, determined solely by the labour use in the traded sector. Since in this case a foreign exchange gift reduces the labour use in the traded sector without affecting relative productivity, it can permanently reduce the growth rate.

Next, consider the case with Cobb–Douglas preferences. When  $\sigma = 1$  it can be verified from the expression in footnote 6 that the effect from  $\lambda_t$  on the labour share in the non-traded sector is zero. From Eq. (15) it can then be seen that there is no feedback from  $\lambda_t$  on its own growth rate. With a constant foreign exchange gift  $R_t$  the labour share is thus constant irrespective of the productivity growth in the two sectors. Consequently, the sectors will in general have different growth rates (except in the special case where  $u\eta(1 - \delta_N) = v(1 - \eta)(1 - \delta_T)$ ). Real consumption of one of the goods grows faster than the

other. With Cobb–Douglas preferences this is exactly matched by an increase in the relative price of the other good so as to keep budget shares, and sectoral labour shares, constant. The asymptotic growth rate of the economy is given by the maximum productivity growth rate from Eqs. (11) and (12). Since the foreign exchange gift increases the non-traded sector labour share permanently, it in general affects the asymptotic growth rate. If the non-traded sector has the highest growth initially, the asymptotic growth rate is given by Eq. (11). The growth rate increases with higher non-traded labour share provided  $u > v\delta_T$ . If the traded sector has the highest growth initially, the asymptotic growth rate is given by Eq. (12). It decreases with higher non-traded labour share provided  $v > u\delta_N$ .

## 5. Dutch disease dynamics

When the (flow of the) foreign exchange gift is permanently increased, the dynamic model is thrown out of steady-state equilibrium. To find how the growth rate of the productivity gap is affected, Eq. (14) is differentiated with respect to  $R_t$ :

$$\frac{d(\dot{\lambda}_t/\lambda_t)}{dR_t} = - [u(1 - \delta_N) + v(1 - \delta_T)] \frac{d\eta(\lambda_t, R_t)}{dR_t} < 0. \quad (17)$$

Hence, after the increased foreign exchange gift, the productivity gap diminishes over time. The phase diagram is affected as indicated by the shift from the solid to the dotted line in Fig. 3. When the foreign exchange gift is increased, the economy jumps vertically from the solid line to the dotted line. From there on the economy moves towards the new dynamic equilibrium,  $\lambda^{**}$ , with the steady-state productivity gap between the traded and the non-traded sector at a lower level.

Fig. 4 shows the development of static equilibria after the initial static equilibrium with an increased foreign exchange gift E2. After the increase in the foreign exchange gift a higher fraction of the workforce is employed in the non-traded sector and, as a consequence, LBD is shifted in favour of this sector. Since we enter a period of faster productivity growth in the non-traded sector than in the traded sector, we know from Section 3 that both the NN curve and the LL curve will shift down over time. Furthermore, with an elasticity of substitution of less than one, the NN curve moves downward faster than the LL curve. Hence, during this process both  $\eta_t$  and  $P_t$  fall. In Fig. 4, the static equilibrium moves southwest over time as indicated by the arrows.

Productivity grows faster in the non-traded sector than in the traded sector as long as the labour share in the non-traded sector is above its steady-state value.

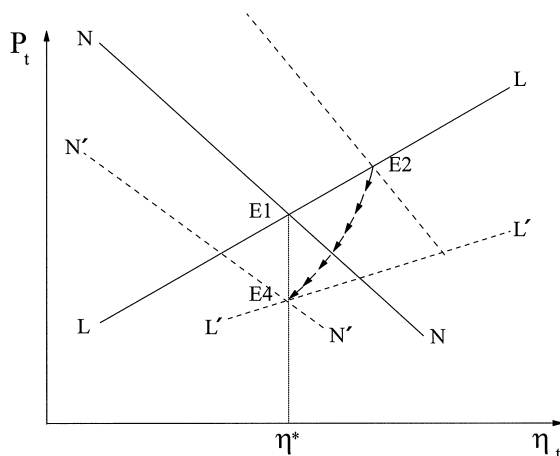


Fig. 4.

Since labour is pushed away from the sector with the fastest productivity growth, the process of a falling labour share will continue until the labour share is back at its original value. Then the economy settles down at the new dynamic equilibrium with a constant relative productivity between the sectors. In the new steady-state relative production has shifted in favour of the non-traded sector as in conventional models of the Dutch disease. Here this is so not because of a new factor allocation, but because of a shift in the steady-state relative productivity between the traded and the non-traded sector.

Since the NN curve shifts faster than the LL curve in Fig. 4, and since the curves will shift downward until  $\eta_t = \eta^*$ , it follows from Fig. 4 that the new dynamic equilibrium is at a point such as E4, where  $L'L'$  intersects  $N'N'$ . The real exchange rate in the new dynamic equilibrium has depreciated also compared with the dynamic equilibrium that ruled before the increased foreign exchange gift. This may seem surprising. After all, if a permanent increase in (the flow of) a foreign exchange gift affects the real exchange rate, it is normally thought that this causes a real appreciation. In this model, the opposite is the result. Analytically this can be verified by inserting for  $\lambda_t$  from (9) in (8), inserting for  $\eta_t = \eta^*$ , and solving for  $P_t$  to get

$$P_t = \left[ \frac{f'(\eta^*)}{g'(1 - \eta^*)} \right]^{1/(\sigma-1)} \left[ \frac{g(1 - \eta^*) + R_t}{f(\eta^*)} \right]^{1/(\sigma-1)}. \quad (18)$$

The steady-state real exchange rate response to increased  $R_t$  is then given by

$$\frac{dP_t}{dR_t} = - \frac{P_t}{(1 - \sigma)[g(1 - \eta^*) + R_t]} < 0. \quad (19)$$

Consequently, the initial real exchange rate response in the static model is a movement away from the new long-run real exchange rate.

The contrast between the real exchange rate result in this model and conventional models deserves some comments. In traditional models two effects typically contribute to real exchange rate appreciation. Using the terminology in Corden and Neary (1982) they are termed ‘spending effect’ and ‘resource movement effect’. The spending effect is analogous to the static effect of an increased foreign exchange gift in the present paper. Higher demand results in a real exchange rate appreciation to stimulate production in the non-traded sector. The resource movement effect may also work in the direction of a real exchange rate appreciation when labour is needed to secure the foreign exchange gift. Then, viewed in isolation, the non-traded supply decreases since less labour is available for the sector. This contributes to a higher price of non-traded relative to traded goods, but is not at work in the present model since no resources are needed to obtain the foreign exchange gift. If capital is also mobile and there are constant returns to scale, as in Corden and Neary (1982, Section IV), the real exchange rate is uniquely determined by the supply side, and is not affected by a foreign exchange gift.

Since the present model has endogenous productivity development, it has an additional determinant of real exchange rate behaviour. It is the relative productivity effect that determines the long-run real exchange rate response. When the composition of employment is shifted in favour of the non-traded sector, this also shifts productivity development in favour of that sector. As productivity rises faster in the non-traded than in the traded sector during the transition period, the real exchange rate depreciates. Since this process continues until the labour allocation is back to its steady-state value, the long-run real exchange rate is determined solely by the change in relative productivity between the two sectors. This is what turns the conventional real exchange rate results around.

Other authors have also pointed out the possibility of a foreign exchange gift causing a real exchange rate depreciation. The mechanism most closely related to the present one is Van Wijnbergen (1984a). In his model, a foreign exchange gift pushes down second-period productivity in the traded sector, and the fall in productivity generates a real exchange rate depreciation. Like the model presented here, the depreciation is a result of the endogenous productivity assumption. In the present model, traded sector productivity can (as will be shown) go both ways. However, a real exchange rate depreciation takes place irrespective of this. The reason is that the long-run real exchange rate behaviour is determined by changes in the steady-state relative productivity between the traded and the non-traded sector, and not by the level of productivity in the traded sector. Mansoorian (1991) shows how heavy external borrowing after a resource discovery cause a real depreciation in the long run. In an overlapping generations model without altruism the generations alive at the time of the discovery

borrow against all future income from these resources. Later generations must service the debt, and long-run aggregate demand will fall. The fall in aggregate demand results in a real exchange rate depreciation. As first pointed out by Corden and Neary (1982, Section III) the real exchange rate may also depreciate when labour is needed to secure the foreign exchange gift and the non-traded sector is the capital intensive one. Applying the Rybczynski theorem, when less labour is available to the traded and non-traded sectors, production in the capital-intensive sector will increase and production in the labour-intensive sector decrease. When the non-traded sector is the capital-intensive one, this factor viewed in isolation increases the supply of non-traded goods, and points to a real exchange rate depreciation. Neary and Purvis (1983, Section 9.2.3) have the possibility of a similar result when the non-traded sector is not capital intensive. In their model capital is needed in the booming natural resource sector, which means that less capital is available for the traded sector. A lower capital stock decreases labour demand in the traded sector, and increases the labour supply for the non-traded sector. The increased labour use in the non-traded sector may be sufficient to create a real exchange rate depreciation. As noted by Corden (1984) a depreciation may also come about if the foreign exchange gift shifts income distribution in the direction of consumers with a lower marginal propensity to consume non-traded goods. Bevan et al. (1990) show how capital restrictions may produce the same exchange rate result. If savings increase as a result of the gift, and it is not possible to invest the increased savings abroad, the capital stock in the non-traded sector may increase sufficiently to result in real exchange rate depreciation. Finally, Rattsø and Torvik (1998) investigate developing countries that are dependent on imported intermediates and face binding foreign exchange constraints. A foreign exchange gift allows for increased imports of intermediates, shifting the non-traded sector supply curve outwards, and causing a real exchange rate depreciation. Hence, the result that the real exchange rate may depreciate as a result of a foreign exchange gift is not a new one. The difference between this paper and the ones discussed above is the mechanism by which it occurs.

## **6. Growth implications**

So far only the development in relative productivity between sectors has been discussed. This is sufficient to determine factor allocation and real exchange rate dynamics. But these are not the only macroeconomic variables of interest. Therefore, attention will now be turned from relative productivities to absolute level productivities.

By inserting the steady-state labour share in the non-traded sector in one of the equations for sectoral productivity growth, the steady-state growth rate  $g$  is



given as

$$g = \frac{uv(1 - \delta_N \delta_T)}{u(1 - \delta_N) + v(1 - \delta_T)}. \quad (20)$$

As expected, the stronger the direct LBD effects, the higher is the growth rate. At first sight one may also expect that the stronger the indirect LBD effects, the higher is the growth rate, but this is not necessarily the case. It can be verified by differentiating (20) that the growth rate increases in  $\delta_T$  if and only if  $(v - u\delta_N) > 0$ . In the same way, the growth rate increases in  $\delta_N$  when  $(u - \delta_T v) > 0$ . Therefore, for the growth rate to increase when the spillover effect from one sector increases, the direct LBD effect in that sector must not be too low compared with the direct and indirect spillovers of the other sector. The intuition for this result is as follows. An increased spillover effect from one sector shifts the steady-state relative productivity in favour of the other sector. Since the sector from which the increased spillover effect originates experiences a fall in relative productivity, it also experiences a rise in steady-state employment. When the direct LBD effect in the sector with increased employment is sufficiently small, this effect is greater than the effect of increased spillover, and the growth rate decreases.

A foreign exchange gift does not affect the steady-state growth rate, but does affect the steady-state levels of production and productivity. This is in contrast to Sachs and Warner (1995) and Gylfason et al. (1997). In these papers a foreign exchange gift permanently reduces employment in the traded sector, and this reduces steady-state growth since it is only the traded sector that generates LBD. Note that since steady-state labour allocation is independent of the foreign exchange gift, the levels of a sector's steady-state productivity and production are two sides of the same coin. In the discussion below, the effects on sectoral productivities of a foreign exchange gift are worked out. All the results regarding sectoral productivities are also valid for sectoral production.

The effects on steady-state sectoral productivities of a foreign exchange gift are found from the transitional dynamics of the model. The productivity developments between steady states depend on the development of  $\eta_t$ . As seen in the previous section,  $\eta_t > \eta^*$  in the movement from the old steady-state to the new one. Consequently, to find how the productivity levels in the new steady-state are affected by the foreign exchange gift, it is sufficient to study the connection between labour allocation and sectoral productivities in the two sectors.

From Eqs. (11) and (12), it can be verified that non-traded sector productivity growth in the transition to the new steady-state increases if  $(u - \delta_T v) > 0$ , and that traded sector productivity growth increases if  $(\delta_N u - v) > 0$ . To make the intuition clear, assume that a worker is transferred from the traded to the non-traded sector. In the non-traded sector the direct LBD effect means that productivity growth increases by  $u$ , while the indirect LBD effect means that

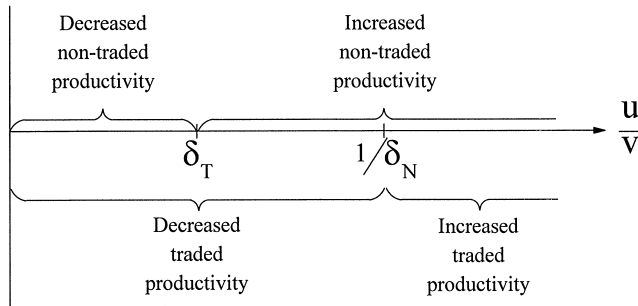


Fig. 5.

productivity growth decreases by  $\delta_T v$ . If the direct LBD effect dominates the indirect one, productivity in the non-traded sector increases. In the same way, the direct LBD effect in the traded sector means that productivity growth decreases by  $v$ , while the indirect LBD effect increases productivity growth by  $\delta_N u$ . For the productivity in the traded sector to increase, the indirect LBD effect has to dominate the direct one.

Fig. 5 shows how the levels of sectoral steady-state productivities (and production) are changed by a foreign exchange gift.<sup>9</sup> If  $u/v$  is less than  $\delta_T$ , the direct LBD effect dominates in the traded sector while the indirect LBD effect dominates in the non-traded sector. In the new steady-state, productivity in both sectors is lower than it would have been had the foreign exchange gift not increased. If  $u/v$  is between  $\delta_T$  and  $1/\delta_N$ , direct effects dominate in both sectors, and productivity in the non-traded sector is higher and productivity in the traded sector lower than without an increased foreign exchange gift. Finally, if  $u/v$  is higher than  $1/\delta_N$ , the indirect effect dominates in the traded sector while the direct effect dominates in the non-traded. Then, both sectors have higher productivity than they otherwise would. The likelihood that the foreign exchange gift will reduce productivity (and production) in both sectors is higher the lower the LBD effect of employment in the non-traded sector, and the higher the LBD effect of employment in the traded sector. The larger the spillover effect from the traded sector, the more likely it is that non-traded productivity will drop. The smaller the spillover effect from the non-traded sector, the more likely it is that traded productivity will drop.

Since Van Wijnbergen (1984a) and Krugman (1987) both assume that  $u = \delta_T = \delta_N = 0$ , they assume away the direct LBD effect in the non-traded sector, and indirect effects in both sectors. This explains the result that

<sup>9</sup>Note that steady-state production and productivities grow by the rate  $g$ . What is referred to as 'increased' or 'decreased' productivity and production, is therefore whether the growth path is above or below the path that would have prevailed without the increase in the foreign exchange gift.

non-traded sector productivity is unchanged and traded sector productivity lower with the Dutch disease. Since Sachs and Warner (1995) assume that  $u = \delta_N = 0$  and  $\delta_T = 1$ , they assume that the traded sector is only affected by the direct LBD effect, while the non-traded sector is only affected by the indirect LBD effect. This is the reason they obtain the result that productivity in both sectors decreases with an increased foreign exchange gift.

In the exogenous productivity models of the Dutch disease, an increased foreign exchange gift reduces tradeables production. The exception is Mansoorian (1991) where heavy borrowing in the short run means that a larger traded sector is needed in the long run. So far the literature on endogenous productivity and the Dutch disease has added another factor that points to reduced tradeables production, namely lower productivity in the traded sector. Furthermore, by combining a perfect indirect LBD spillover from the traded sector with no direct LBD in the non-traded sector, production and productivity in the non-traded sector also fall. The present model hopefully clarifies that these results stem from the restrictive assumptions regarding LBD employed in the models. By allowing for a more general LBD specification, it is relatively straightforward to work out when the productivity results of the earlier LBD models are valid and when they are not.

Since the present model may give rise to increased productivity in the traded sector, the standard result of decreased production of tradeables may be turned around. Neary and Van Wijnbergen (1986, p. 44), who term the traded sector the industrial sector, made the observation that ‘to date no convincing model has been constructed which predicts that a resource boom will generate *both* proindustrialisation and a real depreciation’. Later, Mansoorian (1991) has showed that proindustrialisation and real exchange rate appreciation may result in the long run from ‘excessive’ borrowing in the short run. Heavy borrowing leads to long-run real exchange rate depreciation since aggregate demand will fall at a later stage, and results in proindustrialisation because a larger traded sector is now needed to service the foreign debt. The present model shows another mechanism that may give the same result, but for a different reason. When  $u/v > 1/\delta_N$ , traded sector productivity and production expands because the positive productivity spillover from the non-traded sector is stronger than the negative LBD effect in the traded sector.<sup>10</sup>

If  $u/v$  is low rather than high, a similar result as in Sachs and Warner (1995) appears. When  $u/v < \delta_T$ , the Dutch disease is associated with a lower level of production also in the non-traded sector.<sup>11</sup> In contrast to Sachs and Warner (1995), who assume exogenous relative productivity between the sectors, the

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<sup>10</sup> Note that the increase in traded sector productivity will always be smaller than the increase in non-traded sector productivity. Proindustrialisation in the sense that the traded sector will make up a larger *fraction* of total production will therefore not occur.

<sup>11</sup> In economies where this is the case, the term ‘disease’ clearly makes sense.

present model involves a larger decrease in traded sector productivity than in non-traded sector productivity.

If direct LBD effects dominate in both sectors, productivity in the traded sector decreases while productivity in the non-traded sector increases. Nor is this result included in the earlier literature on LBD and the Dutch disease. It is somewhat surprising that the case where the direct channels dominate has not previously been studied.

There is no a priori reason to expect foreign exchange gifts to work in the same way in different countries. However, the existing models of the Dutch disease seem to go too far in this direction. Economic structure is assumed away by postulating that LBD can only be generated in one out of two sectors. Assumptions regarding learning spillovers take a form which seems too extreme. Other assumptions, which are more realistic for many countries, may turn conventional results around. Maybe Norway's petroleum wealth has increased LBD and productivity in both the traded and the non-traded sector. And maybe the effect of foreign aid in Zimbabwe is not only lower productivity and production in the traded sector, but also in the non-traded sector. As a result of restrictive assumptions, the existing LBD models may contain both a too pessimistic and a too optimistic view of foreign exchange gifts.

## **7. Concluding remarks**

There are two main reasons the mechanisms and results in this paper differ somewhat from earlier models of LBD and the Dutch disease. The first is that LBD can be generated in both the traded and the non-traded sector. The second is the modelling of learning spillovers between sectors. Some new insight has hopefully been gained on two aspects. First, a foreign exchange gift shifts steady-state relative productivity in favour of the non-traded sector, and this results in real exchange rate depreciation, also compared with the situation that prevailed before the foreign exchange gift. Second, the existing literature on LBD and the Dutch disease may yield overly pessimistic conclusions for some countries, but at the same time may be too optimistic for others. It has been shown that depending on the characteristics of the economy at hand, production and productivity in both the traded and non-traded sector can go either way. This is in contrast to the earlier models of the Dutch disease.

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