ISSN 1503-299X

WORKING PAPER SERIES

No. 1/2003

OPTIMAL DUTCH DISEASE

Egil Matsen
Ragnar Torvik

Department of Economics

Norwegian University of Science and Technology
N-7491 Trondheim, Norway
www.svt.ntnu.no/iso/wp/wp.htm

Optimal Dutch Disease

Egil Matsen and Ragnar Torvik*
Norwegian University of Science & Technology†

October 28, 2002

Abstract

Growth models of the Dutch disease, such as those of Krugman (1987), Matsuyama (1992), Sachs and Warner (1995) and Gylfason et al. (1999), explain why resource abundance may reduce growth. However, the literature also raises a new question: if the use of resource wealth hurts productivity growth, how should such wealth be optimally managed? This question forms the topic of the present paper, in which we extend the growth literature on the Dutch disease from a positive to a normative setting. We show that the assumptions in the previous literature imply that the optimal share of national wealth consumed in each period needs to be adjusted down. However, some Dutch disease is always optimal. Thus lower growth in resource abundant countries may not be a problem in itself, but may be part of an optimal growth path. The optimal spending path of the resource wealth may be increasing or decreasing over time, and we discuss why this is the case.

Keywords: Growth. Foreign Exchange Gifts. Resource Wealth. Optimal Saving. Current Account Dynamics.

JEL: F43, O41, Q32.

---

*We are grateful to seminar participants at Harvard University for their helpful comments and suggestions.

†Adress: Department of Economics, NTNU, Dragvoll, NO-7491 Trondheim, Norway. Emails: egil.matsen@svt.ntnu.no, ragnar.torvik@svt.ntnu.no

1 Introduction

There is now a large body of literature claiming that resource abundance lowers growth. Such findings in the case studies by Gelb (1988) have later been confirmed in other case studies by Karl (1997) and Auty (1999, 2001) as well as in econometric studies by Sachs and Warner (1995, 1997, 2001), Gylfason et al. (1999) and Busby et al. (2002).[1] The most widespread theoretical explanation of this apparent puzzle is found in models of the Dutch disease[2], where resource abundance shifts factors of production away from sectors generating learning by doing (LBD).[3] Studies by van Wijnbergen (1984), Krugman (1987), Matsuyama (1992), Sachs and Warner (1995) and Gylfason et al. (1999) all find that when the exploitation of more natural resources shrinks the traded (or industrial) sector, LBD and thus productivity growth is reduced. This literature has been most influential in explaining why resource wealth may lower growth. However, little attention has been given to the question of how resource wealth *should* be managed given that the use of such wealth lowers productivity growth. This is the topic of the present paper.

The seminal contribution on the Dutch disease with endogenous productivity is the two period model by van Wijnbergen (1984), where second period productivity in the traded sector depends on first period production of traded goods. Although van Wijnbergen does not directly discuss how the resource wealth should be optimally managed, the paper includes normative analysis on the design of subsidies. However, the later growth literature on the topic has neglected the normative aspects. Krugman (1987), Sachs and Warner (1995), Gylfason et al. (1999) and Torvik (2001) consider an exogenous flow

[1] For a paper that questions the empirical connection between resource abundance and growth, see Stijns (2002).

[2] Normally the term 'Dutch disease' refers to adverse effects on the traded sector when resource income pushes domestic demand up. The term has also been used to refer to the possible negative growth effects following the reallocation of production factors. However, as we will show, even in the case where growth decreases, this may be the optimal response to resource abundance. Despite this, we choose to use the term 'disease' as this is firmly established among economists.

[3] Other explanations include theories of rent-seeking (Lane and Tornell, 1996; Tornell and Lane, 1999; Baland and Francois, 2000; Torvik, 2002; Mehlum et al., 2002) and political economy theories of why resource abundance invites bad policy choices (Ross, 1999, 2001; Robinson et al., 2002).

of resource income in each period and trace out the growth effects.[4] The present paper extends this growth literature from a positive to a normative setting. To do so we simply adopt the same assumptions regarding productivity growth as the earlier literature and then derive the implications for optimal consumption, management of resource wealth, and growth.

Given the influential contributions on the linkage between LBD and the Dutch disease, the implications of this literature for the optimal management of resource wealth should clearly be of some interest. We show that the LBD mechanism in the earlier literature implies that the optimal share of national wealth consumed in each period needs to be adjusted down. However, a positive fraction of the resource wealth should be consumed in each period – some Dutch disease is always optimal. Thus, lower growth in resource abundant countries may not be a problem in itself, but may be part of an optimal growth path. When the market interest rate equals the social rate of time preference, open economy models with zero or exogenous growth imply a flat optimal consumption path. However, the optimal solution of the present model in this case implies a rising consumption path. The optimal Dutch disease is thus sufficiently weak for each generation to consume more than the preceding generation. The spending path of the resource wealth may be increasing or decreasing over time. A positive growth potential with LBD pulls in the direction of large transfers to early generations, while a negative effect on productivity growth from using the resource wealth pulls in the other direction. The higher the share of non-traded goods in consumption, the weaker is the first effect and the stronger is the second. Thus, the more important that non-traded goods are as a proportion of consumption, and the less important traded goods are, the more likely it is that the optimal spending path of the resource wealth is increasing over time.

The rest of the paper is organized as follows. The model is presented in Section 2. Section 3 derives optimal consumption, while the implications for optimal current account and output growth are discussed in Section 4. Section 5 concludes the paper.

[4]The resource abundance effect in each period is also exogenous in Matsuyama (1992), represented by the productivity of land.

2 The model

Following other models of the Dutch disease, we consider a small open economy that produces traded (T) and non-traded (N) goods. The single most important assumption in the models concerns what factor drives productivity growth. With the exception of Torvik (2001), the literature assumes that productivity growth is generated through LBD in the traded sector only. Van Wijnbergen (1984), Krugman (1987), Matsuyama (1992) and Gylfason et al. (1999) assume that LBD only benefits the sector where it is generated, while productivity in the rest of the economy is constant. Thus, these studies involve models of unbalanced growth. Sachs and Warner (1995), on the other hand, have balanced growth, as they assume that the learning benefits the traded and non-traded sector in the same way.[5] Here we adopt the same LBD mechanism as Sachs and Warner (1995).[6] Denoting the (fraction of the total) labor force employed in the traded sector in period t by η_t, the dynamics of productivity H are:

$$\frac{H_{t+1} - H_t}{H_t} = \alpha \eta_t, \tag{1}$$

where the parameter $\alpha \geq 0$ measures the strength of the LBD effect. As in the earlier literature, the LBD effect is external to firms, the underlying assumption being that each firm is too small to take its own contribution to LBD into account.

Normalizing the size of the labor force to unity, the production functions in the two sectors are given by:

$$X_{Nt} = H_t(1 - \eta_t) \tag{2}$$
$$X_{Tt} = H_t \eta_t \tag{3}$$

where X_{Nt} and X_{Tt} denote production of non-traded and traded goods, respectively. As the model at each point in time has constant returns to scale,

[5] A discussion of the Dutch disease literature can be found in Torvik (2001), who develops a more general model of learning by doing, and derives conditions for when resource abundance does or does not reduce growth.

[6] We chose the specification in Sachs and Warner (1995) because, in addition to its influence on the recent literature on the topic, the unbalanced growth mechanisms in the other papers contain predictions that might seem problematic. For instance, although it is not discussed by the author, the model in Krugman (1987) implies that the real exchange rate approaches infinity.

the real exchange rate (i.e. the relative price of non-tradables in terms of tradables) is uniquely determined by the supply side, as in Corden and Neary (1982, Section IV), for example. The equal productivity in (2) and (3) implies that the real exchange rate is simply equal to 1. By (2) and (3) total production (GDP) in period t is:

$$X_t = X_{Nt} + X_{Tt} = H_t \tag{4}$$

Consumers live for one period (which we think of as a generation). There is a representative individual in each generation. This consumer's labor supply is fixed, he or she has no bequest motive, and allocates spending on non-traded and traded goods according to a Cobb-Douglas felicity function. Let $\gamma \in (0,1)$ be the weight on traded goods in the felicity function. The demand for non-traded goods is thus:

$$C_{Nt} = (1-\gamma)Y_t = X_{Nt}, \tag{5}$$

where Y_t is disposable income for generation t and the last equality shows that in equilibrium domestic demand of non-traded goods must be matched by domestic production of such goods.

Notice that in the absence of a public sector (and thus intergenerational transfers) as well as of a foreign exchange gift we have $Y_t = H_t$, since the relative price of the two goods is one. As there is no private saving, the demand for traded goods is $C_{Tt} = \gamma Y_t$. It then follows from (2) and (5) that $\eta_t = \gamma$, implying that the output growth rate is $\alpha\gamma$ in this case.

2.1 The social planner's problem

The social planner's horizon is M periods, where $M > 1$. Thus there are two inefficiencies in the model: the representative individuals have too short planning horizons and they ignore LBD in their allocation decisions. Potentially, therefore, there is a role for the government in the model, even in the absence of resource wealth. In general, however, we assume that the country receives resource wealth in the form of a foreign exchange gift W_1 at the beginning of period 1. The planner then decides (in period 1) how to allocate this gift over time, and we let R_t be net lump-sum transfers to generation t.

The objective is to maximize:

$$U = \sum_{t=1}^{M} \left(\frac{1}{1+\delta}\right)^{t-1} \left[\gamma \log C_{Tt} + (1-\gamma)\log C_{Nt}\right],$$

where δ is the social rate of time preference. This formulation implies that the planner's elasticity of intertemporal substitution is constant and equal to one.

It turns out be convenient to rewrite the objective function in terms of aggregate consumption. From the static demand functions and the fact that disposable income with transfers is $Y_t = H_t + R_t$, aggregate consumption in period t is:

$$C_t = C_{Tt} + C_{Nt} = \gamma Y_t + (1-\gamma) Y_t = R_t + H_t.$$

Again using the static demand functions, we now have:

$$\gamma \log C_{Tt} + (1-\gamma) \log C_{Nt} = \log C_t + \gamma \log \gamma + (1-\gamma) \log(1-\gamma).$$

Ignoring the constant terms, the social welfare function can thus be written as:

$$U = \sum_{t=1}^{M} \left(\frac{1}{1+\delta} \right)^{t-1} \log C_t, \tag{6}$$

It is important to keep in mind that $C_t = R_t + H_t$, since R is the policy instrument in the model.

In choosing the optimal path for R_t, the planner takes into account the fact that spending the gift in period t affects future productivity. Using (2) and (5), we find that traded sector employment is given by:

$$\eta_t = \gamma - (1-\gamma) \frac{R_t}{H_t}. \tag{7}$$

(7) shows the static effect that is often termed the Dutch disease. Transferring resource income R to generation t increases demand for traded and non-traded goods. As increased demand for non-traded goods must be met by domestic production, resources are drawn out of the traded sector and into the non-traded sector. The effect is stronger the more important non-tradables are in consumption, and the larger transfers are relative to production. Corden and Neary (1982), Corden (1984), Neary and Purvis (1983) and Neary and van Wijnbergen (1986) provide detailed discussions of this and other effects of resource income in models without productivity growth.

Remark 1 *Since $\eta_t \in (0,1)$, equation (7) gives the following restrictions on the ratio of transfers to GDP:*

$$-1 < \frac{R_t}{H_t} < \frac{\gamma}{1-\gamma}, \forall t.$$

The first inequality simply states that negative transfers (i.e. taxes) cannot be higher than 100 % of GDP, while the second inequality says that the transfer-GDP ratio must be lower than the ratio of tradables to non-tradables in aggregate consumption. All the solutions presented below are assumed to obey these restrictions.

Substituting (7) into (1), we find that productivity (and GDP) in period $t+1$ is:

$$H_{t+1} = H_t(1+\alpha\gamma) - \alpha(1-\gamma)R_t. \tag{8}$$

(8) shows the dynamic effect often associated with the Dutch disease. As in van Wijnbergen (1984), Krugman (1987), Sachs and Warner (1995) and Gylfason et al. (1999) generation t's spending of the foreign exchange gift R has a negative effect on future productivity because employment in the traded sector, and thus productivity growth, is reduced. The effect is stronger the stronger is the LBD effect and the more important are non-tradables in aggregate consumption. The reason for the latter is that a large proportion of non-tradables in consumption greatly reduces traded sector employment when demand increases.

So far our model has added nothing important to the earlier endogenous growth models of the Dutch disease. As in the models of Krugman (1987), Sachs and Warner (1995), Gylfason et al. (1999) and Torvik (2001), we have simply shown that when assuming that LBD is generated in the traded sector, the use of resource income lowers growth. However, in the remainder of the paper, we depart from the earlier growth models. While these models assume exogenous resource income at each point in time as well as an exogenous current account, our aim is to find the optimal intertemporal use of resource income and the implied optimal current account and growth dynamics. We thus extend the endogenous growth models of the Dutch disease from a positive to a normative setting.

To derive the intertemporal budget constraint, we make use of the economy's current account. Assuming that the foreign exchange gift is the only initial foreign asset and that there is a constant exogenous real interest rate

r, the current account in period t can be written as:

$$\begin{aligned} CA_t &= W_{t+1} - W_t = X_{Tt} - C_{Tt} + X_{Nt} - C_{Nt} + rW_t \\ &= \eta_t H_t - \gamma(H_t + R_t) + rW_t \\ &= \gamma H_t - (1-\gamma)R_t - \gamma(H_t + R_t) + rW_t \\ &= rW_t - R_t. \end{aligned} \tag{9}$$

The second row follows from (3), the demand function for traded goods, and the equilibrium condition (5). The third row follows from (7). Equation (9) highlights the fact that the planner's problem may be viewed as the task of choosing the optimal current account over time. By repeated iterative substitutions for $W_{t+1}, W_{t+2}, ..$ in (9) (in the manner of Obstfeld and Rogoff (1996, ch. 2.1)), we arrive at the economy's intertemporal budget constraint:

$$\sum_{t=1}^{M} \left(\frac{1}{1+r}\right)^{t-1} R_t = (1+r)W_1. \tag{10}$$

In (10), we have also imposed the terminal condition $W_{M+1} = 0$; the planner will use all the resources his or her budget constraint allows.

2.2 National wealth

As stated above, the planner's problem is to maximize (6) subject to (8), (9) and the terminal condition. This problem is more easily analyzed however by merging (8) and (9) into one constraint, describing the dynamics of national wealth. At the start of period $t+1$, the planner's measure of national wealth is:

$$NW_{t+1} = (1+r)W_{t+1} + \sum_{s=t+1}^{M} \left(\frac{1}{1+r}\right)^{s-(t+1)} H_s. \tag{11}$$

It includes (financial/natural resource) wealth accumulated through period t plus the present value of current and future income. Next, we observe that repeated iterative substitutions in (8) implies that GDP in period $s > t$ can be written as:

$$H_s = (1+\alpha\gamma)^{s-t} H_t - \alpha(1-\gamma) \sum_{i=t}^{s-1} (1+\alpha\gamma)^{s-1-i} R_i.$$

Using this and equation (9) in (11), we can express national wealth in period $t+1$ as:

$$NW_{t+1} = (1+r)\left[(1+r)W_t - R_t\right] + (1+r)\sum_{s=t+1}^{M}\left(\frac{1+\alpha\gamma}{1+r}\right)^{s-t} H_t$$
$$-\alpha(1-\gamma)\sum_{s=t+1}^{M}\left(\frac{1}{1+r}\right)^{s-(t+1)}\left[(1+\alpha\gamma)^{s-(t+1)}R_t\right.$$
$$\left. + \sum_{i=t+1}^{M}(1+\alpha\gamma)^{s-1-i}R_i\right]. \quad (12)$$

This *single* dynamic constraint now replaces the two constraints (8) and (9) in the planner's maximization problem. We notice that the period t spending of the foreign exchange gift enters the constraint via two terms. The first term represents the ordinary effect of lower future financial/natural resource wealth, while the second term represents the negative effect on future income through lower productivity growth. Given this formulation of the budget constraint, we can also restate the terminal condition as $NW_{M+1} = 0$.

Later, we will also make use of a more familiar form of (national) wealth dynamics. From (11), we have:

$$\begin{aligned} NW_{t+1} &= (1+r)[(1+r)W_t - R_t] + (1+r)\sum_{s=t}^{M}\left(\frac{1}{1+r}\right)^{s-t} H_s - (1+r)H_t \\ &= (1+r)\left[(1+r)W_t + \sum_{s=t}^{M}\left(\frac{1}{1+r}\right)^{s-t} H_s - C_t\right] \\ &= (1+r)\left(NW_t - C_t\right). \end{aligned} \quad (13)$$

3 Optimal aggregate consumption

We shall first present the solution for optimal aggregate consumption. As will become clear below, our model has interesting implications for the optimal intertemporal consumption allocation compared to models either without growth or with exogenous growth.[7] The planner chooses $\{R_t\}$ to maximize

[7] A non-growing economy can be studied within our framework when there is no LBD, i.e. when $\alpha = 0$. A model with exogenous growth can be analyzed by considering the

(6) subject to (12) and the terminal condition. In solving this problem, we make one assumption:

Assumption 1: $r > \alpha\gamma$.

This is a sufficient condition for positive consumption in all periods (see below). In effect it states that the interest rate is higher than the economy's output growth in the absence of government intervention, and is standard in open economy growth models.

Proposition 1 *Let*

$$J(NW_t) = \max_{R_t} \sum_{t=1}^{M} \left(\frac{1}{1+\delta}\right)^{t-1} \log(R_t + H_t),$$

subject to (12) and the terminal condition. Then:

$$J(NW_t) = \Phi_t + \Theta_t \log NW_t,$$

where $\Theta_t = \frac{1+\delta}{\delta}\left[1 - \left(\frac{1}{1+\delta}\right)^{M-t}\right]$ *and* Φ_t *is an inessential function of time only. Optimal consumption is:*

$$C_t = h_t NW_t, \tag{14}$$

where

$$h_t \equiv \frac{1}{1 + \left[\frac{1+\delta}{\delta}\left(1 - \left(\frac{1}{1+\delta}\right)^{M-t+1}\right) - 1\right]\left[1 + \frac{\alpha(1-\gamma)}{r-\alpha\gamma}\left(1 - \left(\frac{1+\alpha\gamma}{1+r}\right)^{M-t}\right)\right]} \tag{15}$$

Proof. See the appendix. ■

By applying equation (13) and (14) it is now straightforward to demonstrate that aggregate consumption grows according to:

$$\frac{C_{t+1}}{C_t} = (1+r)\frac{h_{t+1}}{h_t}(1-h_t) \tag{16}$$

in optimum. Although the optimal consumption growth rate is generally time-varying and non-linear, an important intuition can be provided:

borderline case of $\gamma = 1$. Our country would then produce and consume tradables only, in effect giving us a one-sector model with an exogenous output growth rate $= \alpha$.

Corollary 1 *Compared to non-growing economies or economies with exogenous growth, learning by doing implies that it is optimal to consume a lower fraction of national wealth in any period, except for the last period $t = M$.*

Proof. (A) That $h_M = 1$ regardless of the size of α or γ follows directly from (15).[8] (B) In any period $t < M$, the last square bracket in the denominator of (15) is (i) larger than 1 if $\alpha > 0$ and $\gamma < 1$, and (ii) equal to 1 if $\alpha = 0$ or $\gamma = 1$. Hence $h_{t|\alpha=0} = h_{t|\gamma=1} > h_{t|\alpha>0,\gamma<1}$, $t < M$. ■

The intuition behind Corollary 1 is that consumption is more costly in our endogenous growth model. In our economy increased consumption in one period not only lowers future financial wealth, it also lowers future productivity growth. In other words, saving an extra euro in our model gives interest *plus* higher production in the future. Hence, it is optimal to save more than in economies either without growth or with exogenous growth. Moreover, the consumption-wealth ratio increases faster over time with LBD.

Further intuition on the result of the optimal consumption growth can be provided by considering asymptotic properties of our model, i.e. when $M \to \infty$. When the planner has a very long time horizon, equation (15) gives:

$$\lim_{M\to\infty} h_t = \frac{\delta}{1+\delta+\frac{\alpha(1-\gamma)}{r-\alpha\gamma}}, \tag{17}$$

which is a constant. We note that when $\alpha = 0$ (zero growth) or when $\gamma = 1$ (exogenous growth), a constant share $\frac{\delta}{1+\delta}$ of national wealth should be consumed in each period. But with LBD, a lower constant share of national wealth should be consumed in each period. Furthermore, from (17) and (16) we have:

$$\lim_{M\to\infty} \frac{C_{t+1}-C_t}{C_t} = \frac{r\left(1+\frac{\alpha(1-\gamma)}{r-\alpha\gamma}\right)-\delta}{1+\delta+\frac{\alpha(1-\gamma)}{r-\alpha\gamma}}.$$

Thus with an infinite planning horizon, the optimal consumption growth rate is a constant. The first term in the numerator on the right-hand side of this expression can be interpreted as the effective interest rate with an infinite horizon in our model. It gives the marginal return from saving in the infinite

[8] It also follows from combining (15) with the terminal condition $NW_{M+1} = 0$.

horizon case. The planner would tilt the optimal consumption path up or down according to the difference between this adjusted interest rate and the rate of time preference. For instance, with $r = \delta$ it would be optimal with constant consumption in non-growing or exogenous growth economies. In our model, however, this parameter combination implies a growing optimal consumption path. Again, this is because the effective interest rate is higher than r in our setup, increasing optimal saving.[9]

4 Optimal transfers and output growth

The optimal path for aggregate consumption discussed above has implications for how the foreign exchange gift should be phased into the economy. This section derives the optimal spending path, from which the paths for output and the current account follow. As the optimal consumption growth rate in general is time-varying and non-linear, the analytical solutions of the model become quite complex for horizons of more than two to three periods. To highlight the intuition behind our model we therefore proceed in two steps. First, we discuss the analytical solution in the two-period case in some detail. Second, we show numerical paths to highlight the intuition in the general case.

4.1 An example with $M = 2$

With $M = 2$, from (15) we have $C_2 = NW_2$ and $C_1 = \frac{1+\delta}{2+\delta+\frac{\alpha(1-\gamma)}{1+r}} NW_1$. Then (16) gives us:

$$\frac{C_2}{C_1} = \frac{1+r}{1+\delta}\left(1 + \frac{\alpha(1-\gamma)}{1+r}\right). \tag{18}$$

LBD implies higher optimal consumption growth than in models with zero or exogenous growth. Since $C_t = H_t + R_t$, (18) can be expressed as:

$$R_2 + H_2 = (R_1 + H_1)\left[\frac{1+r}{1+\delta}\left(1 + \frac{\alpha(1-\gamma)}{1+r}\right)\right].$$

[9] With an infinite horizon our solution may be in conflict with $\eta_t \in (0, 1)$, as in Matsuyama (1992). In that case one needs to maximize (6) subject to (12) *and* $\eta_t \in (0, 1)$. We do not pursue this matter further.

Substituting for H_2 from (8), we find that second period spending of the foreign exchange gift is:

$$\begin{aligned} R_2 &= \left[\frac{1+r}{1+\delta}\left(1+\frac{\alpha(1-\gamma)}{1+r}\right)+\alpha(1-\gamma)\right]R_1 \\ &\quad+\left[\frac{1+r}{1+\delta}\left(1+\frac{\alpha(1-\gamma)}{1+r}\right)-(1+\alpha\gamma)\right]H_1. \end{aligned} \tag{19}$$

Let us pause here and temporarily assume that $r=\delta$:

- Without LBD ($\alpha = 0$) equation (19) would reduce to $R_2 = R_1$, which from (10) implies that $R_1 = \frac{(1+r)^2}{2+r}W_1$. This ensures that the two generations are given equal amounts of the foreign exchange gift.

- Within an exogenous growth framework ($\gamma = 1$), (19) gives $R_2 = R_1 - \alpha H_1$. Applying (10), we find $R_1 = \frac{(1+r)^2}{2+r}W_1 + \frac{1}{2+r}\alpha H_1$. The planner would now increase transfers to generation 1 with a share $1/(2+r)$ of the exogenous output growth from period 1 to 2.

- Using (19) in (10), our two-sector, LBD framework implies:

$$R_1 = \frac{(1+r)^2}{2+r+\frac{2+r}{1+r}\alpha(1-\gamma)}W_1 + \frac{\alpha\gamma - \frac{\alpha(1-\gamma)}{1+r}}{2+r+\frac{2+r}{1+r}\alpha(1-\gamma)}H_1. \tag{20}$$

  The higher the foreign exchange gift W_1, the higher the transfers to generation 1 should be. However, with LBD it is optimal to transfer a lower fraction of the foreign exchange gift than is otherwise the case.

  In the absence of a foreign exchange gift, transfers to the first generation are positive provided that $\gamma - \frac{(1-\gamma)}{1+r} > 0$, and negative if the opposite is the case. The intuition for this is that the two effects pull in opposite directions. On the one hand, with a positive growth potential ($\alpha > 0$) the planner would like to transfer resources away from generation 2 towards generation 1. On the other hand, transferring resources to generation 1 is costly in terms of lower output growth. This cost is higher the more a given amount of transfers push down traded sector employment, and thus learning. The larger the share of non-traded goods in consumption ($1-\gamma$), the more costly are transfers to generation one in terms of future output. Thus for a sufficiently high ($1-\gamma$), transfers to the first generation are negative.

Whereas $r = \delta$ implies that the foreign exchange gift should be spread out in equal amounts in a non-growing economy, the first generation should receive more than the second with exogenous growth. With endogenous growth, this effect may very well be reversed. It is costly in terms of lower future output to spend the gift today, and so the planner may in fact transfer less to generation 1 compared to a non-growing economy.

Leaving the case of $r = \delta$, we can use (19) in (10) to find the general expression for optimal R_1:

$$R_1 = \frac{(1+r)^2}{1+r+\frac{1+r}{1+\delta}+\frac{2+\delta}{1+\delta}\alpha(1-\gamma)}W_1 + \frac{1+\alpha\gamma-\frac{\alpha(1-\gamma)}{1+r}-\frac{1+r}{1+\delta}}{1+r+\frac{1+r}{1+\delta}+\frac{2+\delta}{1+\delta}\alpha(1-\gamma)}H_1. \quad (21)$$

Without the foreign exchange gift R_1 is negative if the last numerator in (21) is < 0. It then follows from (8) that the optimal output growth rate is higher than the 'market solution' implies. If the nominator is > 0, the optimal growth rate is less than in the 'market solution', as in the optimal solution more resources should have been transferred to the present generation even when this leads to lower growth.

Equation (21) also shows us that R_1 is unambiguously increasing in W_1. Thus, the optimal output growth path decreases when the country receives a foreign exchange gift. In contrast to the positive growth models of the Dutch disease, such as Krugman (1987), Matsuyama (1992), Sachs and Warner (1995), Gylfason et al. (1999) and Torvik (2001), which tend to view lower growth as a problem resulting from foreign exchange gifts, we have shown that this is in fact an optimal response.

The implications for the current account are straightforward: ceteris paribus, LBD implies less consumption of the foreign exchange gift in period 1, giving a smaller current account deficit (larger surplus). Using (21) in (9), the current account in period 1 is:

$$CA_1 = \frac{r\left(\frac{1+r}{1+\delta}+\alpha(1-\gamma)\frac{2+\delta}{1+\delta}-1\right)-1}{1+r+\frac{1+r}{1+\delta}+\alpha(1-\gamma)\frac{2+\delta}{1+\delta}}W_1 + \frac{\frac{\alpha(1-\gamma)}{1+r}+\frac{1+r}{1+\delta}-(1+\alpha\gamma)}{1+r+\frac{1+r}{1+\delta}+\alpha(1-\gamma)\frac{2+\delta}{1+\delta}}H_1,$$

which in general has an ambiguous sign.

4.2 General case

To find the optimal spending of the foreign exchange gift when $M > 2$, we start by rewriting (16) as:

$$R_{t+1} + H_{t+1} = \left[(1+r)\frac{h_{t+1}}{h_t}(1-h_t)\right](R_t + H_t),$$

which in combination with (8) implies:

$$\begin{aligned} R_{t+1} \quad &= \quad \left[(1+r)\frac{h_{t+1}}{h_t}(1-h_t) + \alpha(1-\gamma)\right] R_t \\ &\quad - \left[1 + \alpha\gamma - (1+r)\frac{h_{t+1}}{h_t}(1-h_t)\right] H_t. \end{aligned} \tag{22}$$

Equations (8) and (22) comprise a system of difference equations that the two endogenous variables R and H have to fulfill in the optimum.

For horizons longer than two to three periods, the analytical solutions quickly become complex, and we illustrate the intuition with numerical simulations.

Parameters and initial state variable values

Each time period (generation) is 25 years and the planner has a planning horizon of 250 years, i.e. $M = 10$. In our benchmark simulations we set r and δ equal at 85.4 %. This corresponds to annual time preference rates and interest rates of 2.5 %. The traded goods expenditures share is set to $\gamma = 0.4$. We start out with a moderate LBD effect, using $\alpha = 0.1$ in our benchmark simulation. We normalize the first period's GDP, which is predetermined, to $H_1 = 100$. Finally, we assume that the country receives a substantial foreign exchange gift $W_1 = 25$, corresponding to about six years of initial period production.

Benchmark results

Chart 1 displays the optimal path of production, foreign exchange gift spending, foreign assets, and the current account, given the parameters and initial state variable values above.[10]

Chart 1 about here

[10] To limit the number of paths, we leave out the path for aggregate consumption; it is simply the sum of H and R in each period.

Both output H and transfers R grow over time, but whereas output growth decreases through time, the growth in R increases (although this is barely visible in the chart, the effect is there). As it is optimal to spend relatively little of the foreign exchange gift in the first periods, the country initially builds up its foreign assets further. Not until period 7 does the planner start to run current account deficits CA. We notice that since R grows faster than output, equation (7) implies that employment in the traded sector optimally decreases over time.

To put these results into perspective, we display the corresponding paths in a non-growing economy ($\alpha = 0$) and an economy with exogenous growth ($\gamma = 1$) in charts 2 and 3 respectively. Without growth, all generations receive the same share of the foreign exchange gift, equal to the annuity value of the gift. As a result, the nation runs a current account deficit in each period, albeit at an increasing pace. (Up to and including period 6, the deficit is smaller than 1 % of GDP.) As there is a constant ratio between R and H, employment in the two sectors in this case is constant.

Chart 2 about here

Interestingly, chart 3 shows the opposite patterns for W, R, and CA compared to those in chart 1. With exogenous growth, the spending path for the foreign exchange gift should decrease over time. Foreign assets should decline at a rapid pace initially, and the current account should be negative until period 8 and then positive. We notice that this ensures equal consumption for each generation, whereas the endogenous growth framework in chart 1 implies increasing consumption over time. Again, this is because the optimal real interest rate for consumption decisions is in effect larger within our LBD framework.

Chart 3 about here

Sensitivity analysis

Chart 4 displays the paths for output H (in the upper graphs) and transfers R (in the lower graphs) for different values of α. The higher is α, the more concave is the output path, and the more convex is the spending path of the foreign exchange gift. For higher values of α, the optimal R should start at a lower level and then increase faster the closer we are to the time horizon. The resulting output growth is one of fast initial growth that slows as we approach period M.

** Chart 4 about here **

Turning to the effect of the traded goods expenditure share γ, we have already seen from charts 1 and 3 above that different values can have important effects on the solution. While $\gamma = 0.4$ implies an increasing spending path, $\gamma = 1$ gives a negatively sloped optimal spending path. The opposite slopes of the spending paths reflect a fundamental trade-off that the planner faces in our model: *on the one hand output growth generally implies that the early generations should receive a larger share of the foreign exchange gift (as in an exogenous growth model), but on the other hand, spending should be postponed because of its adverse effect on future productivity.* The effect that pulls in the direction of large transfers to early generations is *stronger* the higher is γ, as a large expenditure share on traded goods implies a large traded sector and thus a high growth potential for any given level of total demand. The effect that pulls in the direction of postponing spending, on the other hand, is *weaker* the larger is γ. This is because a large expenditure share on traded goods and a small expenditure share on non-traded goods ensures that little of an extra euro in demand is directed towards the non-traded sector. That is, higher demand does not greatly reduce traded sector employment (and thus productivity growth). Therefore, there is little gain in future productivity from postponing spending.

Thus, there is some value of γ where the two effects cancel, giving a constant optimal spending path. Holding other parameters fixed, $\gamma \approx 0.466$ gives a constant spending path in our example. Chart 5 illustrates the effect on optimal output and spending for three different values of γ. The higher is γ, the faster is optimal output growth (shown in the upper graphs) and the larger is the share of the foreign exchange gift that should be allocated to the first generations (shown in the lower graphs). We notice that although the optimal path for R falls for a sufficiently high γ, optimal aggregate consumption would increase over time in our model for all $\gamma < 1$.

** Chart 5 about here **

The effect on the spending path from a higher interest rate is analogous in our model to that in non-growing or exogenous growth economies. In all cases optimal saving increases and so the R path becomes steeper. However, in our endogenous growth framework, this would also imply that output growth increases initially and then becomes lower as M approaches. Likewise, an increase in the rate of time preference lowers optimal saving in all models considered, implying that it would be optimal to distribute more of the foreign exchange gift to the first generations. As a consequence optimal output growth would decrease initially and increase in later periods in the LBD model.

5 Conclusions

In this paper we have extended the growth literature on the Dutch disease from a positive to a normative setting. Adopting the same assumptions that were used in the earlier growth literature on the Dutch disease, we have derived the implications for optimal saving of resource wealth and the corresponding optimal growth of consumption and output. LBD implies that the optimal share of national wealth consumed in each period needs to be adjusted downwards. However, some Dutch disease is always optimal in the sense that a positive fraction of the resource wealth should be consumed in each period. We have seen that the optimal consumption decision differs from models of both zero and exogenous growth. The spending path of the resource wealth may be increasing or decreasing over time. The more important non-traded goods are as a proportion of consumption, and the less important traded goods are, the more likely it is that the optimal spending path of the resource wealth is increasing over time.

The growth literature on the Dutch disease has provided important contributions towards understanding why resource abundance may reduce growth. In addition the literature has raised new questions that need to be analyzed in a normative setting. If the use of resource wealth hurts productivity growth, an important question is how such wealth should then be managed. We hope the present paper has provided some initial answers to this question.

6 References

Auty R.M. (1999) "The transition from rent-driven growth to skill-driven growth: recent experience of five mineral economies." In: Maier, J., Chambers, B., Farooq, A. (eds.) *Development Policies in Natural Resource Economies*, Edward Elgar, Cheltenham.

Auty R.M. (2001) *Resource Abundance and Economic Development*, Oxford University Press, Oxford.

Baland, J.-M. and P. Francois. (2000) "Rent-seeking and resource booms." *Journal of Development Economics* 61: 527-542.

Busby, G., J. Isham, L. Pritchett and M. Woolcock (2002) "The varieties of rentier experience: how natural resource export structures affect the political economy of economic growth." Mimeo, The World Bank.

Corden, W.M. (1984) "Booming sector and Dutch disease economics: survey and consolidation." *Oxford Economic Papers* 36: 359-380.

Corden, W.M. and J.P. Neary (1982) "Booming sector and de-industrialisation in a small open economy." *Economic Journal* 92: 825-848.

Gelb A. (1988) *Windfall Gains: Blessing or Curse?*, Oxford University Press, Oxford.

Gylfason, T., T.T. Herbertsson and G. Zoega (1999) "A mixed blessing: Natural resources and economic growth." *Macroeconomic Dynamics* 3: 204-225.

Karl, T.L. (1997) *The Paradox of Plenty: Oil Booms and Petro States*, University of California Press, Berkeley.

Krugman, P. (1987) "The narrow moving band, the Dutch disease, and the competitive consequences of Mrs. Thatcher: notes on trade in the presence of dynamic scale economies." *Journal of Development Economics* 37: 41-55.

Lane, P.R. and A. Tornell (1996) "Power, growth and the voracity effect." *Journal of Economic Growth* 1: 213-241.

Matsuyama, K. (1992) "Agricultural productivity, comparative advantage and economic growth." *Journal of Economic Theory* 58: 317-334.

Mehlum, H., K.O. Moene and R. Torvik (2002) "Institutions and the resource curse." Mimeo, Department of Economics, University of Oslo.

Neary, J.P. and D.D. Purvis (1983) "Real adjustment and exchange rate dynamics." In: Frenkel, J.A. (ed.) *Exchange Rates and International Macroeconomics*, University of Chicago Press, Chicago.

Neary, J.P. and S. van Wijnbergen (1986) "Natural resources and the macroeconomy: a theoretical framework." In: Neary, J.P., van Wijnbergen, S. (eds.) *Natural Resources and the Macroeconomy*, Blackwell, Cambridge.

Obstfeld, M. and K. Rogoff (1996) *Foundations of International Macroeconomics*, MIT Press, Cambridge, MA.

Robinson, J.A., R. Torvik and T. Verdier (2002) "Political foundations of the resource curse." CEPR Discussion Paper No. 3422.

Ross, M.L. (1999) "The political economy of the resource curse." *World Politics* 51: 297-322.

Ross, M.L. (2001) *Timber Booms and Institutional Breakdown in Southeast Asia*, Cambridge University Press, New York.

Sachs, J.D. and A.M. Warner (1995) "Natural resource abundance and economic growth." NBER Working Paper No. 5398.

Sachs, J.D. and A.M. Warner (1997) "Sources of slow growth in African economies." *Journal of African Economies* 6: 335-376.

Sachs, J.D. and A.M. Warner (2001) "The curse of natural resources." *European Economic Review* 45: 827-838.

Stijns, J.P. (2002) "Natural resource abundance and economic growth revisited." Mimeo, Department of Economics, UC Berkeley.

Tornell, A. and P.R. Lane (1999) "The voracity effect." *American Economic Review* 89: 22-46.

Torvik, R. (2001) "Learning by doing and the Dutch disease." *European Economic Review* 45: 285-306.

Torvik, R. (2002) "Natural resources, rent seeking and welfare." *Journal of Development Economics* 67: 455-470.

van Wijnbergen, S. (1984) "The 'Dutch disease': a disease after all?" *Economic Journal* 94: 41-55.

A Proof of proposition 1

For the proposed value function J_t, the Bellman optimality equation is:

$$\begin{aligned}&\Phi_t + \Theta_t \log NW_t \\ = \; &\max_{R_t} \left[\log(R_t + H_t) + \frac{1}{1+\delta} (\Phi_{t+1} + \Theta_{t+1} \log NW_{t+1}) \right], \end{aligned} \quad \text{(A.1)}$$

subject to (12). The first-order condition can be written as:

$$\begin{aligned} C_t^{-1} &= \frac{\Theta_{t+1}}{1+\delta}\left[1+r+\alpha(1-\gamma)\sum_{s=t+1}^{M}\left(\frac{1+\alpha\gamma}{1+r}\right)^{s-t+1}\right] NW_{t+1}^{-1} \\ &= \frac{1+r}{1+\delta}\Theta_{t+1}\left[1+\frac{\alpha(1-\gamma)}{r-\alpha\gamma}\left(1-\left(\frac{1+\alpha\gamma}{1+r}\right)^{M-t}\right)\right] NW_{t+1}^{-1}. \end{aligned}$$

Inverting this expression, substituting for NW_{t+1} from (13), and simplifying gives:

$$\begin{aligned} C_t &= \frac{(1+r)(1+\delta)}{(1+r)(1+\delta)+(1+r)\Theta_{t+1}\left[1+\frac{\alpha(1-\gamma)}{r-\alpha\gamma}\left(1-\left(\frac{1+\alpha\gamma}{1+r}\right)^{M-t}\right)\right]} NW_t \\ &\equiv h_t NW_t. \end{aligned} \tag{A.2}$$

Substituting for C in (A.1) gives:

$$\begin{aligned} \Phi_t + \Theta_t \log NW_t &= \log\left(h_t NW_t\right) \\ &\quad + \frac{1}{1+\delta}\left\{\Theta_{t+1}\log\left[(1+r)(1-h_t)NW_t\right]+\Phi_{t+1}\right\} \\ &= \left(1+\frac{1}{1+\delta}\Theta_{t+1}\right)\log NW_t \\ &\quad + \log h_t + \frac{\Phi_{t+1}}{1+\delta} + \frac{\Theta_{t+1}}{1+\delta}\log\left((1+r)(1-h_t)\right). \end{aligned}$$

Thus, the proposed value function is established for:

$$\Theta_t = 1 + (1+\delta)^{-1}\Theta_{t+1}, \tag{A.3}$$

and:

$$\Phi_t = \log h_t + \frac{\Phi_{t+1}}{1+\delta} + \frac{\Theta_{t+1}}{1+\delta}\log\left((1+r)(1-h_t)\right).$$

(A.3) can be evaluated recursively by observing that $\Theta_M = 1$. Hence, $\Theta_{M-1} = 1 + \frac{1}{1+\delta}$, $\Theta_{M-2} = 1 + \frac{1}{1+\delta} + \left(\frac{1}{1+\delta}\right)^2$, etc. In general,

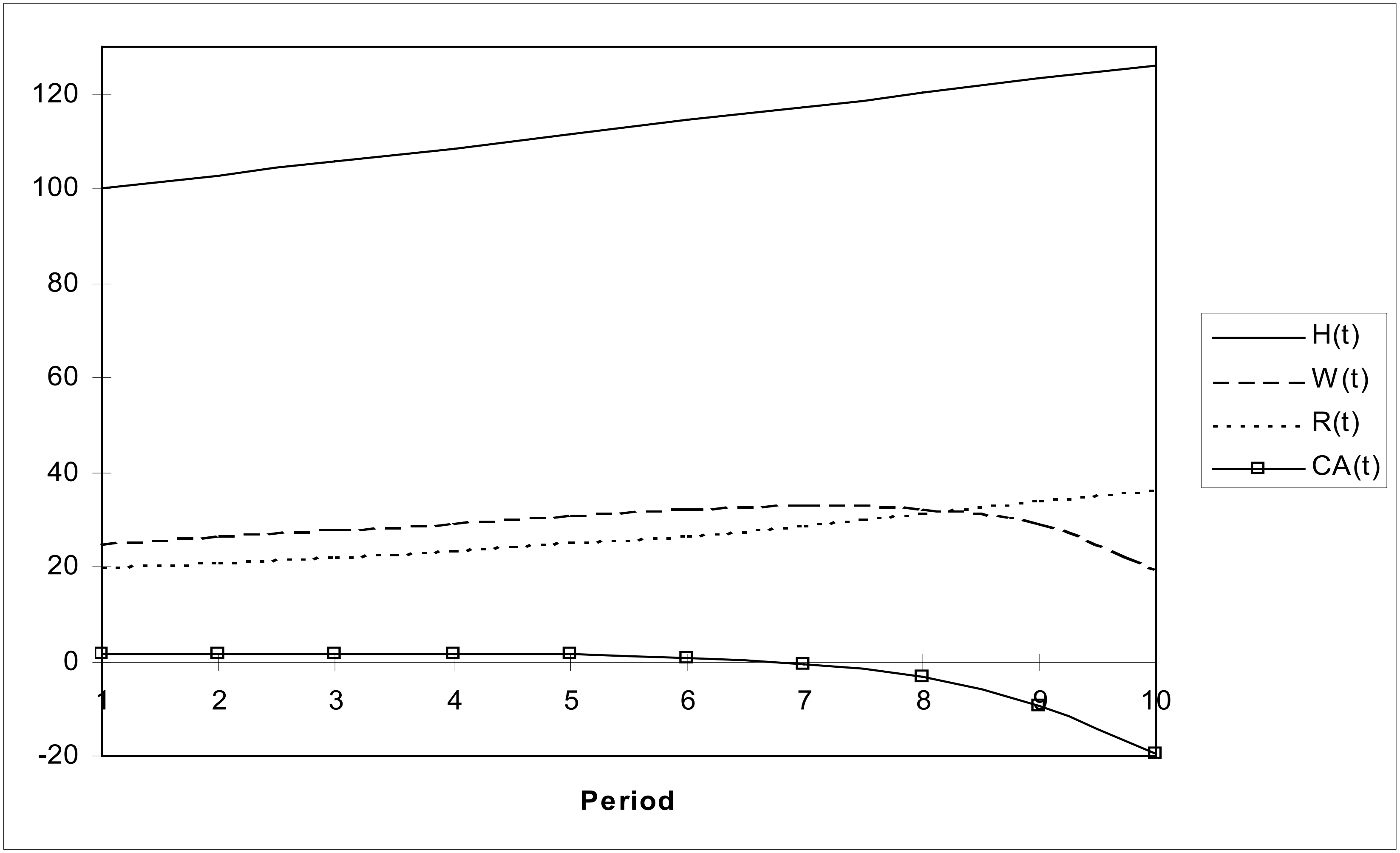
$$\begin{aligned} \Theta_t &= 1 + \frac{1}{1+\delta} + \left(\frac{1}{1+\delta}\right)^2 + \cdots + \left(\frac{1}{1+\delta}\right)^{M-t} \\ &= \frac{1+\delta}{\delta}\left(1-\left(\frac{1}{1+\delta}\right)^{M-t+1}\right). \end{aligned} \tag{A.4}$$

Applying in (A.2) gives:

$$h_t = \frac{(1+r)(1+\delta)}{(1+r)(1+\delta) + (1+r)(1+\delta)\left(\Theta_t - 1\right)\left[1 + \frac{\alpha(1-\gamma)}{r-\alpha\gamma}\left(1 - \left(\frac{1+\alpha\gamma}{1+r}\right)^{M-t}\right)\right]}.$$

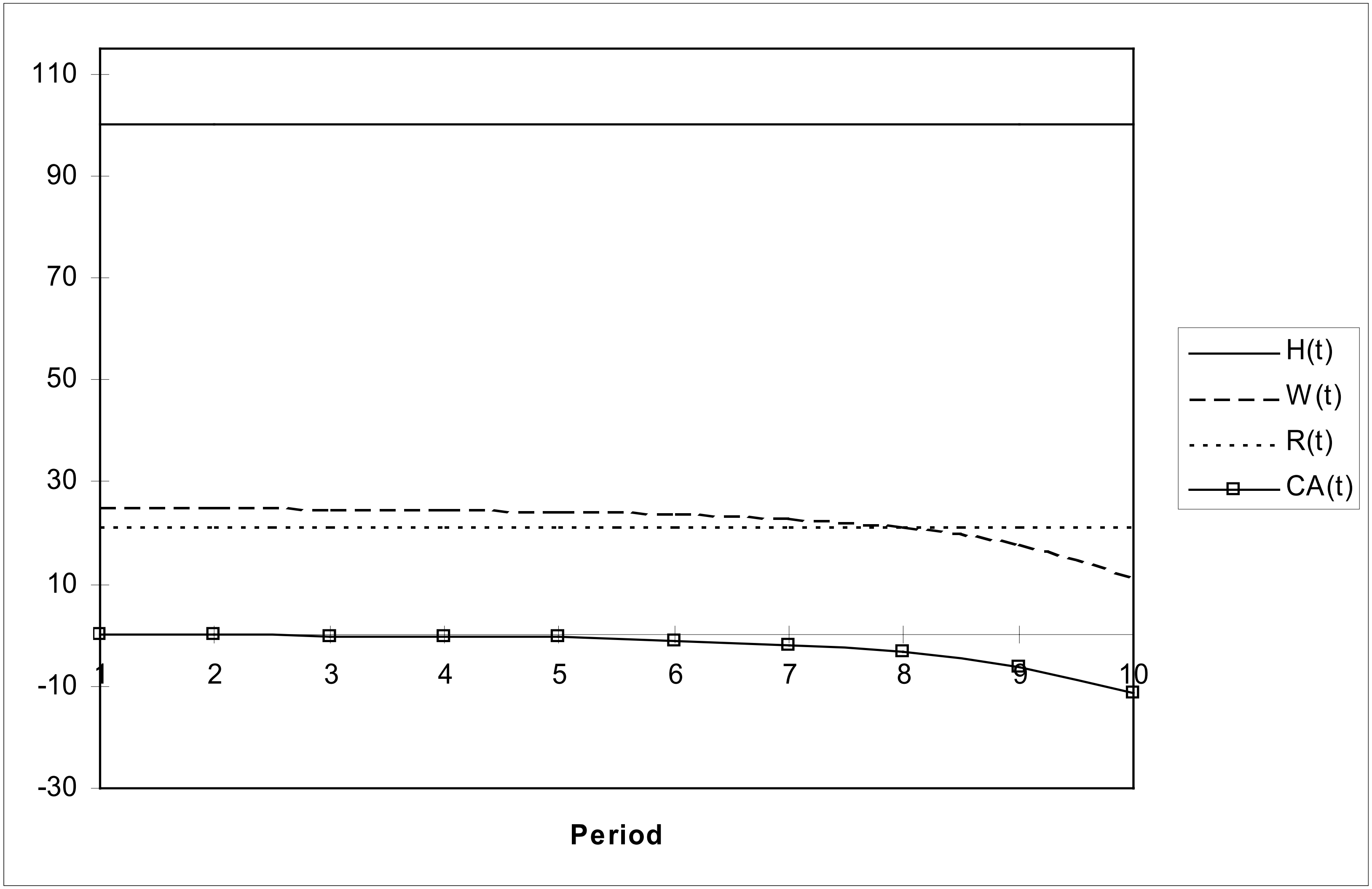
Inserting from (A.4) gives us equation (15), and completes the proof.■

Chart 1: Optimal paths for output, spending of the foreign exchange gift, the current account, and beginning-of-period foreign assets.



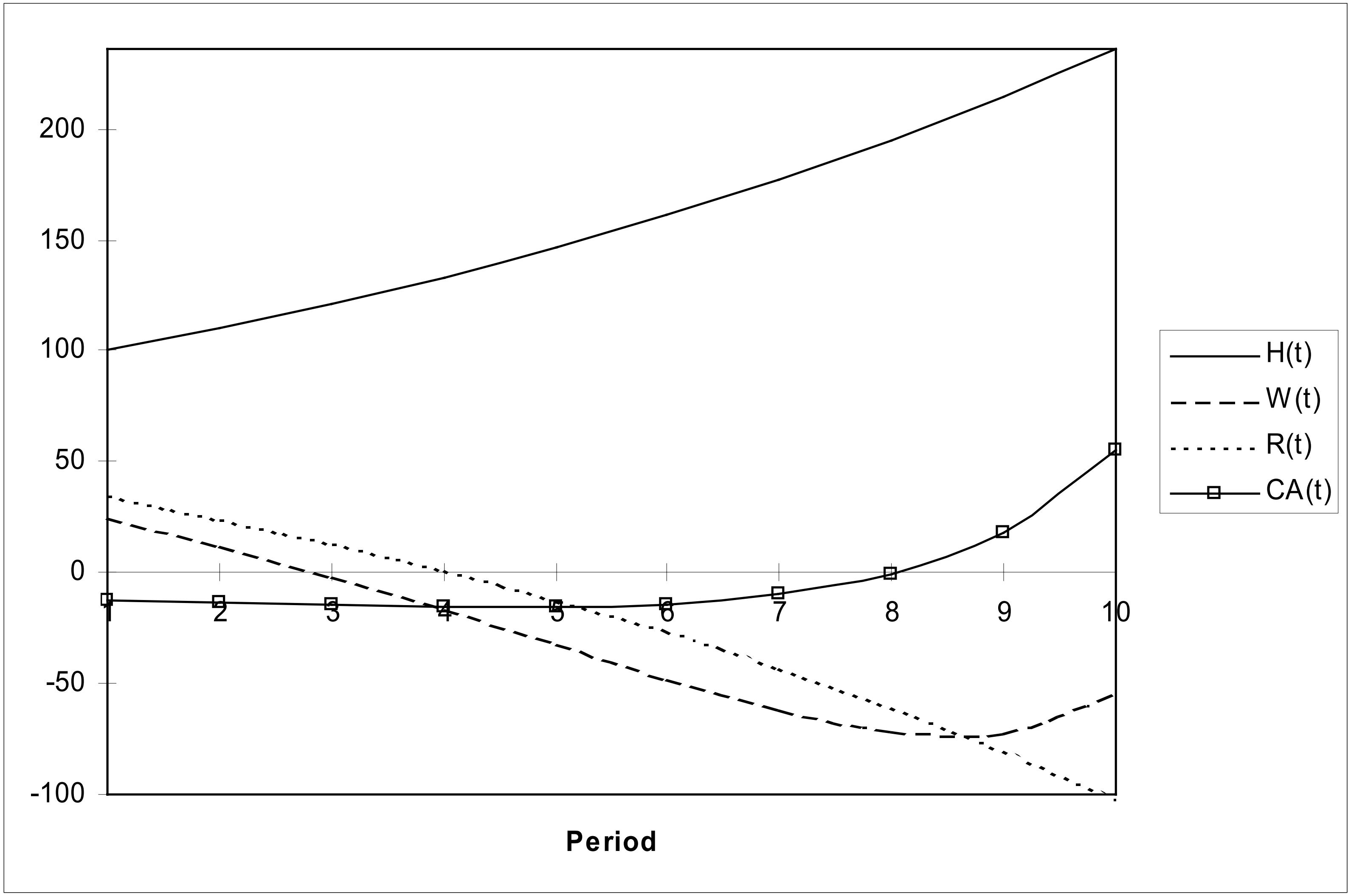
Note: Based on following parameter- and initial state variable values: $r = \delta = 85.4\ \%$, $\alpha = 0.1$, $\gamma = 0.4$, $H_1 = 100$, $W_1 = 25$.

Chart 2: Optimal paths for output, spending of the foreign exchange gift, the current account, and beginning-of-period foreign assets in a non-growing economy.



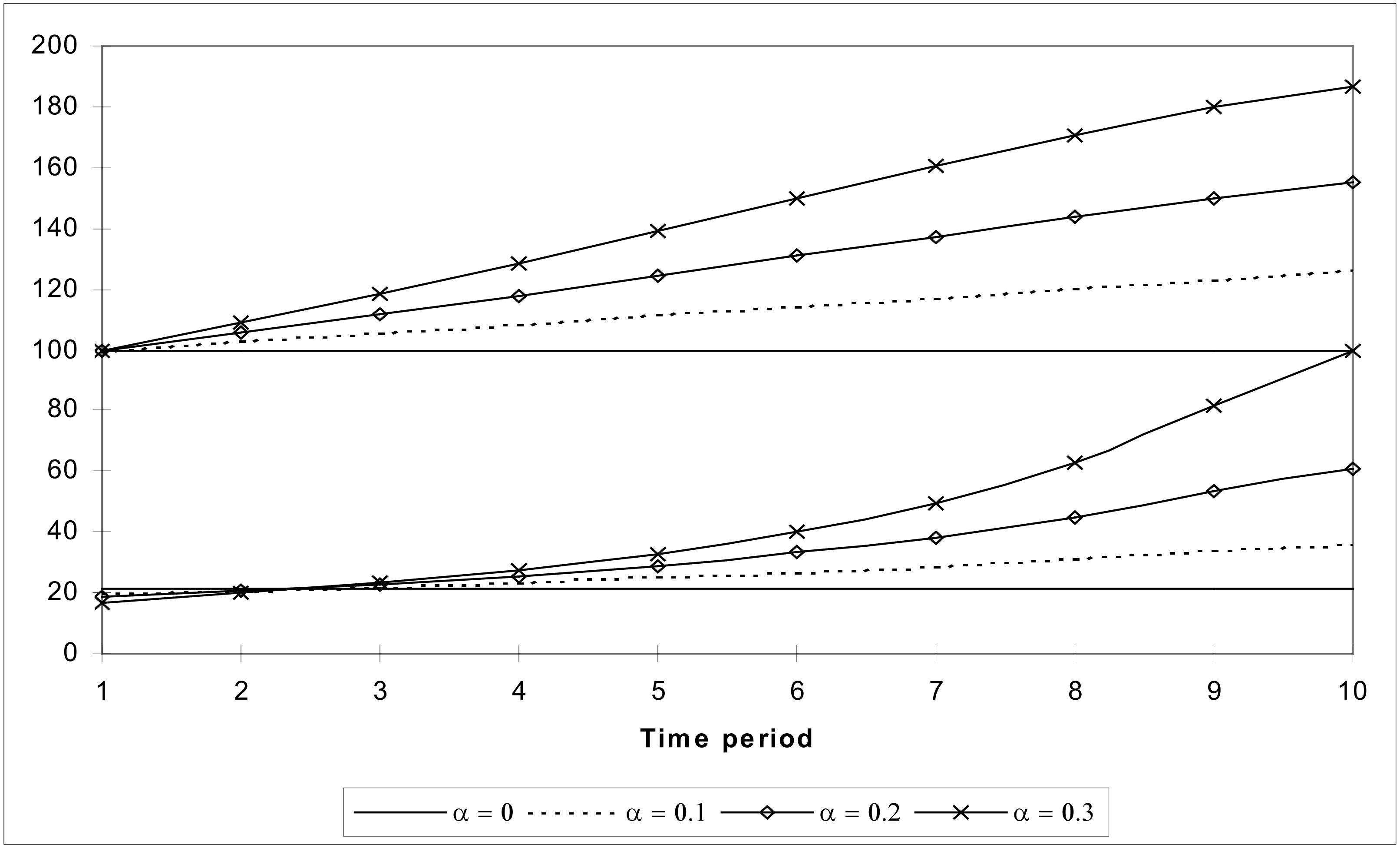
Note: Based on following parameter- and initial state variable values: $r = \delta = 85.4$ %, $\alpha = 0$, $\gamma = 0.4$, $H_1 = 100$, $W_1 = 25$.

Chart 3: Optimal paths for output, spending of the foreign exchange gift, the current account, and beginning-of-period foreign assets in an economy with exogenous growth.



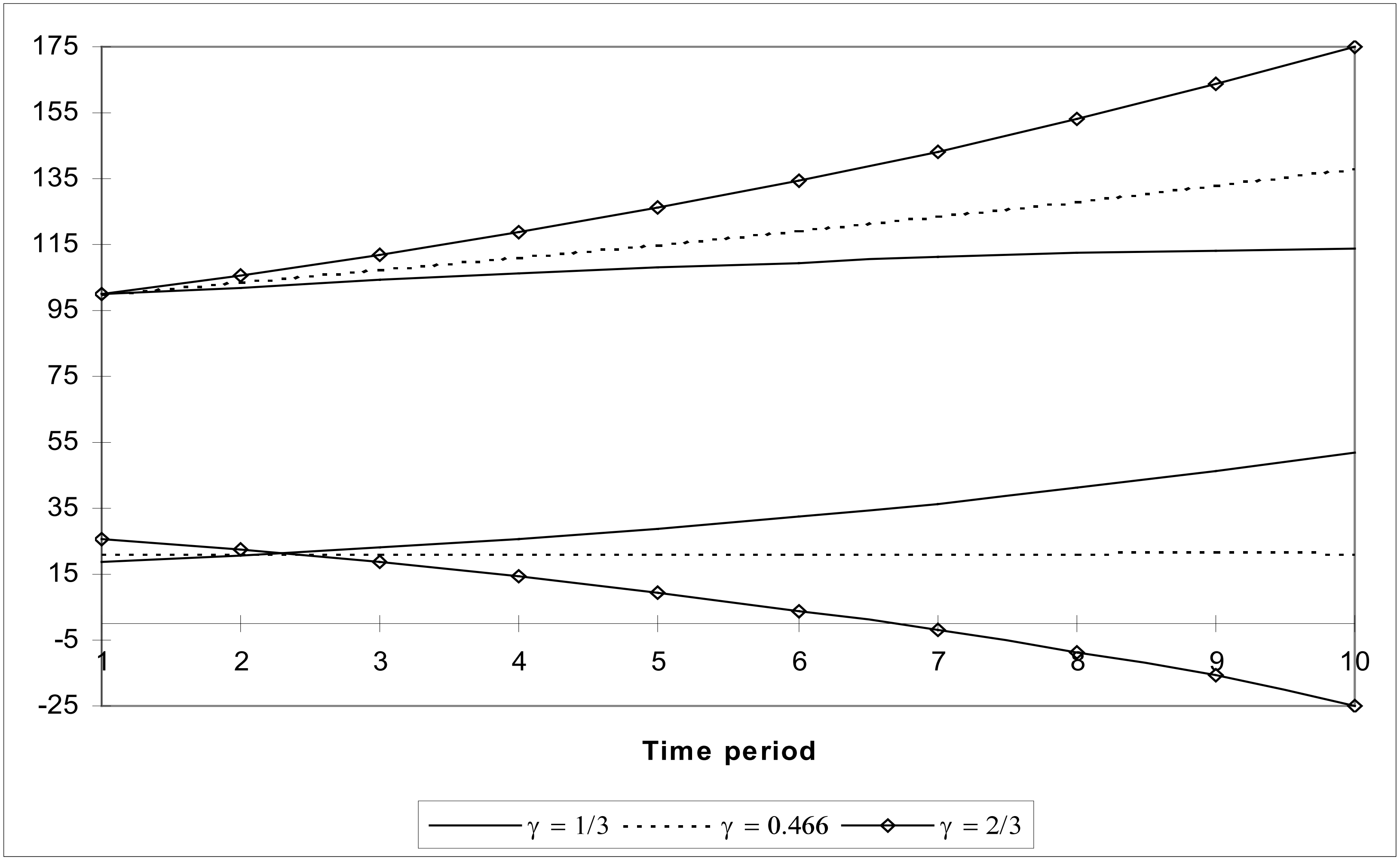
Note: Based on following parameter- and initial state variable values: $r = \delta = 85.4$ %, $\alpha = 0.1$, $\gamma = 1$, $H_1 = 100$, $W_1 = 25$.

Chart 4: Optimal paths for output (upper 4 graphs) and spending of the foreign exchange gift (lower 4 graphs) for different values of α.



Note: Except for α, all parameters and initial state variables have the same values as in Chart 1.

Chart 5: Optimal paths for output (upper 3 graphs) and spending of the foreign exchange gift (lower 3 graphs) for different values of γ.



Note: Except for γ, all parameters and initial state variables have the same values as in Chart 1.