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## Dynamic effects of an anticipated switch from destination- to origin-based commodity taxation

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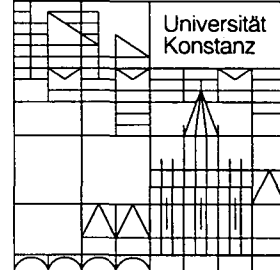
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# **Dynamic Effects of an Anticipated Switch from Destination- to Origin-Based Commodity Taxation**

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### **Abstract**

This paper investigates the macroeconomic and welfare effects of an anticipated future switch from destination- to origin-based commodity taxation. We set up an intertemporal representative agent model of an open economy and study especially consumption, investment and trade balance responses to the commodity tax reform. The anticipation effects on the macroeconomy are significant, whereas their welfare implications are not.

# 1 Introduction

Continuing regional integration in the European Union, but also in North America, has reopened the debate on the proper scheme of taxing international commodity trade. The basic problem is that not all final consumers will be taxed under the current destination principle, when borders are open. Those consumers that cross borders and undertake their purchases abroad pay the value-added tax (VAT) of the respective foreign country rather than the VAT of their country of residence. Hence maintaining the destination principle for producer trade while taxation of part of direct consumer purchases breaks with this principle leads to a hybrid international commodity tax scheme, which distorts the trade pattern in the union. Furthermore, the scheme offers incentives for integrating countries to engage in a mutually harmful process of commodity tax competition in order to attract cross-border shopping and other forms of direct consumer purchases (e.g. Sinn 1990). These effects may be aggravated further when the transaction costs for tax arbitrage in the form of cross-border shopping are reduced in the European monetary union. The potentially serious drawbacks of the current regime have led to a revival of interest in the alternative of taxing all commodity trade under the origin principle.

The issue is, of course, not a new one. A fundamental equivalence between the origin and the destination principle dates back to the Tinbergen Report (European Coal and Steel Community 1953), and the conclusion that only the origin principle of commodity taxation is compatible with a true internal market can already be found in the report of the Neumark Committee (EEC Commission 1963). These reports are, however, based on the assumption that there is no international factor mobility. Recently, several authors have reconsidered the equivalence of origin- and destination-based commodity taxation in a setting with perfect international capital mobility (Krause-Junk 1992, Bovenberg 1994, Genser, Haufler and Sørensen 1995). A common result of these analyses is that a switch to the origin principle reduces the return to 'old' capital, but it does not distort investment decisions and causes no global efficiency losses, if the tax is levied at a uniform rate on all goods. This result puts the origin principle in a rather favourable light and has caused several authors to recommend a switch to this commodity tax scheme for the European Union.<sup>1</sup>

Dynamic analyses of the switch to origin-based commodity taxation have generally

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<sup>1</sup> Another recent argument in favour of the origin principle is that it can be combined with the destination principle for trade with third countries in a non-distortive way (Lockwood, de Meza and Myles 1994). Also, Genser and Schulze (1995) counter the argument that the origin principle – unlike the destination principle – is vulnerable to transfer pricing activity between entities of multinational companies. They argue instead that origin taxation of commodities may actually reduce the incentives for transfer pricing when corporate taxation is included in the analysis and there is a negative relation between value-added and corporate tax rates.

assumed that this switch is unexpected.<sup>2</sup> Bovenberg (1994), for example, provides a comprehensive account of the dynamic effects of an unanticipated switch to an origin-based commodity tax, allowing for both overlapping generations and foreign ownership of domestic equity. In such a setting, the tax switch generates macroeconomic consequences through intergenerational distribution and via a shift of the tax burden to foreigners. In practice, however, it can be virtually excluded that a major tax reform that requires the unanimous consent of all EU member states can be devised so as to surprise capital owners and avoid announcement effects. A full analysis of the commodity tax reform therefore ought to take into account that the lapse of time between the announcement and the actual implementation of the switch may itself generate macroeconomic and possibly welfare effects. In a similar vein, Bradford (1995, pp. 36-37) concludes that the lump-sum character of an unanticipated tax on 'old' capital in connection with a shift from an income tax to a consumption tax probably has been overemphasized in the literature. While he stresses the problems posed by anticipation, he does not present a formal model of the dynamic effects involved.

Our aim in the present paper is to provide an analytical treatment of the macroeconomic and welfare consequences of switching from a destination-based to an origin-based commodity tax, when the switch has been anticipated well in advance. We focus on a small open economy which is well integrated into the world economy and derive how the macroeconomy and welfare of the representative individual are affected by the tax reform. To isolate the anticipation effects, we assume that individuals are infinitely-lived, and – in most of the analysis – that domestic capital is fully owned by domestic citizens. It emerges that after the commodity tax switch has become known, but before it has been implemented, consumption and investment decline, while the trade balance improves. After the reform has been carried out, the opposite effects are registered. One virtue of the analytical approach is that all these effects have straightforward, intuitive explanations, and can be linked directly to the underlying model parameters. As to the welfare effects of an anticipated tax reform, we find that marginal tax changes are not able to affect welfare and even a large reform only produces very limited welfare effects associated with temporary investment distortions and a distortion of the time pattern of consumption.

Apart from the paper by Bovenberg (1994), this paper is related to Nielsen and Sørensen (1991), who discuss a number of scenarios of capital tax reform in a small open economy, including an anticipated tax credit. Our analysis of anticipation effects also contains formal analogies to an analysis of the dynamic effects of a devaluation in the presence of wage stickiness (Nielsen 1991). Finally, there are obvious similarities with a switch to a cash-flow tax on capital, as analyzed in a closed economy framework in Howitt and Sinn

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<sup>2</sup>One exception is the computable general equilibrium analysis of Fehr (1996), of which we became aware in the process of writing this paper. Fehr focuses on the intergenerational and international welfare effects of a switch in the commodity tax principle and numerically compares these effects in the absence and in the presence of a policy pre-announcement.

(1989). However, an anticipated switch in the commodity tax principle raises distinctive issues and for instance necessitates a clearer focus in the analysis on the time pattern of consumption.

The plan of the paper is as follows: Section 2 describes the model and sets up the intertemporal optimization problems of firms and households. Section 3 analyzes the effects of the policy switch on the time paths of firms' investment and households' savings decisions, as well as international asset accumulation. Section 4 turns to the welfare effects of the reform. Section 5 concludes.

## 2 The Model

We consider a small, open economy which faces fixed world prices in both goods and capital markets. There is only one homogeneous output good, which can either be invested or consumed. The world price of this good is normalized to unity, and the real international interest rate is denoted by  $r$ . In the following we separately discuss the optimization problems faced by producers and consumers in the small country, and then describe the tax reform in some more detail.

### 2.1 Firms

In the basic model, the representative firm is owned exclusively by domestic households, which therefore act as consumer-producers. The firm produces output under the time-invariant production function  $f(k_t)$ , where  $k_t$  is the capital stock in period  $t$ . The production function has the usual properties of positive but diminishing returns to capital ( $f' > 0, f'' < 0$ ). The firm invests an amount  $i_t$  in each period. For convenience we introduce a separate variable for the firm's *relative* investment  $h_t \equiv i_t/k_t$ . A standard specification is that investment is subject to convex installation costs  $\varphi(h_t)$ , which are a function of the firm's relative investment (e.g. Blanchard and Fischer 1989, Nielsen and Sørensen 1991). When  $h_t$  equals the exogenous depreciation rate  $\rho$ , then both total and marginal installation costs are zero. For all other investment levels there are positive installation costs and marginal costs increase as the deviation from  $\rho$  increases. The properties of the installation cost function are summarized by

$$\varphi(h_t) > 0 \text{ for } h_t \neq \rho, \quad \varphi(\rho) = 0, \quad \varphi'(\rho) = 0, \quad \varphi''(h_t) > 0. \quad (1)$$

Installation costs consume real resources. To effectively install the investment  $i_t$ , the firm must thus incur total costs of  $i_t(1 + \varphi(h_t))$ . These investment costs are valued at the *producer* price  $p_t$  since all investment costs are tax deductible under consumption taxation. Using  $i_t = h_t k_t$  from the definition of  $h_t$ , the firm's cash-flow in period  $t$  can be written as

$$\pi_t = [f(k_t) - k_t h_t (1 + \varphi(h_t))] p_t. \quad (2)$$



The firm chooses the relative investment level  $h_t$  so as to maximize the present value of its cash flow

$$\max_{h_t} \int_0^\infty e^{-rt} [f(k_t) - k_t h_t (1 + \varphi(h_t))] p_t dt$$

subject to the capital accumulation constraint

$$\dot{k}_t = i_t - \rho k_t = (h_t - \rho) k_t. \quad (3)$$

The current-value Hamiltonian for this problem is

$$\mathcal{H}_F = [f(k_t) - k_t h_t (1 + \varphi(h_t))] p_t + \mu_t (h_t - \rho) k_t,$$

where  $\mu_t$  gives the current value of the co-state variable, i.e. the shadow price of the capital stock. For relative investment, the necessary condition for an optimum implies

$$\mu_t = [1 + \varphi(h_t) + h_t \varphi'(h_t)] p_t \equiv \psi^{-1}(h_t) p_t. \quad (4)$$

The first-order condition (4) shows that investment behaviour is governed by the relative co-state variable ( $\mu_t/p_t$ ). The latter gives the shadow price of the capital stock, relative to the price of capital, and plays the role of “Tobin’s  $q$ ” in the present context. Inverting the function  $(\psi)^{-1}(h_t)$  defined in (4) gives the investment function

$$h_t = \psi\left(\frac{\mu_t}{p_t}\right), \quad \psi(1) = \rho, \quad \frac{\partial \psi}{\partial (\mu_t/p_t)} > 0. \quad (5)$$

Since there is no growth in the present model, only replacement investments are undertaken in the steady state, where the shadow price and the market price of capital coincide ( $\mu_t = p_t$ ). Relative investment will be above (below) the exogenous depreciation rate if and only if the shadow price of capital is above (below) its market price. Substituting  $\psi(\cdot)$  in the equation of motion (3) yields

$$\dot{k}_t = \left[ \psi\left(\frac{\mu_t}{p_t}\right) - \rho \right] k_t. \quad (6)$$

The optimality condition with respect to the state variable implies

$$[f'(k_t) - h_t(1 + \varphi(h_t))] p_t + \dot{\mu}_t = \mu_t(r + \rho - h_t). \quad (7)$$

This condition can be simplified by substituting  $h_t(1 + \varphi(h_t)) p_t = h_t \mu_t - h_t^2 \varphi'(h_t) p_t$  from the first-order condition (4), giving

$$[f'(k_t) + h_t^2 \varphi'(h_t)] p_t + \dot{\mu}_t = \mu_t(r + \rho). \quad (8)$$

Equation (8) implicitly defines the firm’s optimal investment path. On the left-hand side of the equation are the marginal benefits of installing an additional unit of capital in the small country. These consist of three elements: capital’s marginal product, the marginal savings on adjustment costs (both valued at the producer price  $p_t$ ), and the capital gains from

a change in the nominal shadow price of capital. On the right-hand side of the equation are the marginal costs of using capital from one instant to the next, which are composed of the instantaneous interest rate  $r$  and the exogenous depreciation rate  $\rho$ . In the steady state ( $\mu_t = p_t$ ) this, of course, implies that  $f' - \rho = r$ , i.e. the net marginal product of capital must equal the international interest rate. Equations (6) and (8) summarize the dynamic evolution of the capital stock in the small open economy.

## 2.2 Households

There is a representative, infinitely-lived household in the small country, which owns all domestic factors of production (producer-consumer household). In addition, the household can borrow and lend freely in the international capital market, with  $a_t$  denoting the net foreign asset position in period  $t$ . The accumulation constraint for foreign assets is given by

$$\dot{a}_t = ra_t + \pi_t + g_t - q_t c_t, \quad (9)$$

where household income consists of interest income  $ra_t$  on the outstanding foreign asset position, the firm's cash flow  $\pi_t$ , and lump-sum transfers from the government  $g_t$  (which are defined below). The consumption level in period  $t$  is denoted  $c_t$ , and consumption expenditures are valued at the domestic consumer price  $q_t$ .

The household maximizes the discounted sum of instantaneous utilities  $u(c_t)$ . To avoid the well-known problems associated with foreign asset accumulation or decumulation in the steady state in a small open economy we assume that the household's pure rate of time preference equals the world rate of interest. The household's optimization problem is thus described by

$$\max_{c_t} \int_0^{\infty} e^{-rt} u(c_t) dt$$

subject to the accumulation constraint (9) and a transversality ('No Ponzi-game') condition

$$\lim_{t \rightarrow \infty} a_t e^{-rt} = 0. \quad (10)$$

The current-value Hamiltonian of the household's optimization problem is

$$\mathcal{H}_H = u(c_t) + \lambda_t (ra_t + \pi_t + g_t - q_t c_t).$$

From the first-order condition with respect to  $c_t$ , the current value of the co-state variable  $\lambda_t$  is determined as

$$\lambda_t = \frac{u'(c_t)}{q_t}. \quad (11)$$

The first-order condition with respect to the state variable  $a_t$  implies, using (11)

$$\dot{\lambda}_t = 0. \quad (12)$$

According to (12), the shadow price of foreign assets (or the marginal utility of wealth) remains constant over time, but it may jump at  $t = 0$  in response to new information like news on a future tax reform. In conjunction with (11) this implies that after period zero the consumption level will change if and only if the consumer price changes in period  $t$ .

### 2.3 Government

The analysis allows for two types of commodity taxes, a destination-based tax at rate  $z$  and an origin-based tax at rate  $v$ . The destination tax increases the consumer price  $q_t$  in the small country, whereas the origin tax reduces the producer price  $p_t$ . Hence, given the world price of unity, we have

$$q_t = 1 + z, \quad p_t = \frac{1}{(1 + v)}. \quad (13)$$

To close the model we have to specify the government budget constraint. Government revenues in period  $t$  are given by the sum of tax receipts from the destination-based tax and the origin-based tax on the firm's cash flow (production minus investment). Since for simplicity we disregard public consumption, tax revenues are fully returned to the representative consumer as a lump-sum transfer [cf. eq. (9)]. In this case there is no loss of generality by assuming that the government's budget is balanced in each period

$$g_t = zc_t + v\pi_t. \quad (14)$$

From (13), origin- and destination-based taxes can be combined to give the total tax wedge between producer and consumer prices in the small country

$$q_t = (1 + z)(1 + v)p_t \equiv \theta p_t.$$

The policy change analyzed in the following is a marginal switch from destination- to origin-based consumption taxes, which leaves the aggregate tax wedge  $\theta$  unchanged.<sup>3</sup> Totally differentiating gives  $dz = -(1 + z)/(1 + v) dv < 0$ , i.e. a small, exogenous increase in the origin-based tax rate  $v$  is compensated by a reduction in the destination-based tax rate  $z$ . Using (13), the price effects of a compensated increase in  $v$  in period  $t$  are derived as

$$dq_t = dz = -\frac{q_t}{(1 + v)} dv < 0, \quad dp_t = -\frac{p_t}{(1 + v)} dv < 0, \quad (15)$$

so that both consumer and producer prices in the small country will fall in response to the change in the tax scheme. In the long run, these price adjustments ensure that there

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<sup>3</sup>This implies that when the small open economy switches to origin-based commodity taxes, the rest of the world does not. This is the scheme of the non-reciprocal restricted origin principle (Lockwood, de Meza and Myles 1994), where the rest of the world continues to use the destination principle for its trade, even if a subgroup of integrating countries (say, the EU) switches to the origin principle.

are no real effects of a switch from the destination to the origin principle of commodity taxation, except for a change in the net foreign asset position and, consequently, in the level of consumption.<sup>4</sup> In the short run real effects occur, however, when agents anticipate the switch in the tax principle. These adjustment processes are analyzed in detail in the following section.

### 3 Real Effects of an Anticipated Switch in the Tax Regime

#### 3.1 The Investment Path

We linearize the two dynamic equations (6) and (8) around the initial steady state. As a preliminary step, we define the parameter  $\kappa$  to denote the first derivative of the investment function (5), evaluated in the steady state. Using the properties of the installation cost function (1) and the first-order condition (4), we can employ the inverse function rule to get

$$\kappa \equiv \psi'(1) = \left( \frac{\partial(\psi^{-1})}{\partial h_t} \right)^{-1} = \frac{1}{\rho\varphi''(\rho)} > 0. \quad (16)$$

Totally differentiating the equation of motion (6), using (16) and the properties of the initial steady state gives<sup>5</sup>

$$\dot{\hat{k}} = \kappa (\hat{\mu} - \hat{p}), \quad (17)$$

where we have introduced the ‘hat’ notation to describe percentage changes in variables from the steady state. Thus  $\hat{\mu} = d\mu/\mu$ ,  $\hat{p} = dp/p$  and  $\dot{\hat{k}} = d(\dot{k})/k$ .<sup>6</sup>

Similarly, we can totally differentiate the optimal investment condition (8) to get in a first step

$$f'(k)dp + p[f''(k)dk + h^2\varphi''dh] + d(\dot{\mu}) = (r + \rho)d\mu.$$

From the capital accumulation constraint (3) and (17) we get  $dh = d(\dot{k}/k) = \dot{\hat{k}} = \kappa (\hat{\mu} - \hat{p})$ . Using this and the properties of the initial steady state gives<sup>7</sup>

$$\dot{\hat{\mu}} = r(\hat{\mu} - \hat{p}) + \alpha(r + \rho)\dot{\hat{k}}, \quad (18)$$

<sup>4</sup>The latter effect is due to the so-called ‘path dependence’ property in this type of models; see, e.g., Nielsen (1991).

<sup>5</sup>From now on we drop the time subscript  $t$  when no confusion is possible.

<sup>6</sup>Noting that  $\dot{k} = 0$  in the initial equilibrium the last result follows from

$$\dot{\hat{k}} \equiv \frac{\partial(dk/k)}{\partial t} = \frac{k(\partial dk/\partial t) - dk\dot{k}}{k^2} = \frac{1}{k} \frac{\partial(dk)}{\partial t} = \frac{d(\dot{k})}{k}.$$

<sup>7</sup>We use (16) and  $h = \rho$  in the initial steady state to get  $h^2\varphi''dh = \rho(\hat{\mu} - \hat{p})$ . Inserting this and observing that  $f' = r + \rho$  initially [from (8)] and  $d(\dot{\mu}/\mu) = \dot{\hat{\mu}}$  (cf. footnote 6), we can finally divide by  $p = \mu$  [which holds in the initial steady state from (4)] to get (18).

where we have introduced the elasticity of the marginal productivity of capital

$$\alpha \equiv -\frac{f''(k)k}{f'(k)} > 0.$$

Equations (17) and (18) jointly determine the time path for the capital stock  $k$  and the nominal shadow price of capital  $\mu$ . In matrix form, the dynamic investment system is given by

$$\begin{bmatrix} \dot{\hat{k}} \\ \dot{\hat{\mu}} \end{bmatrix} = J \begin{bmatrix} \hat{k} \\ \hat{\mu} \end{bmatrix} + \begin{bmatrix} -\kappa \\ -r \end{bmatrix} \hat{p}, \quad J = \begin{bmatrix} 0 & \kappa \\ \alpha(r + \rho) & r \end{bmatrix}. \quad (19)$$

The determinant of the coefficient matrix  $|J| = -\kappa\alpha(r + \rho)$  is negative, thus ensuring saddle-point stability. The eigenvalues are

$$\eta_1 = \frac{r}{2} - \sqrt{\left(\frac{r}{2}\right)^2 + \kappa\alpha(r + \rho)} < 0, \quad \eta_2 = \frac{r}{2} + \sqrt{\left(\frac{r}{2}\right)^2 + \kappa\alpha(r + \rho)} > 0. \quad (20)$$

They show how the speed of stable, respectively unstable movement of the dynamic investment system depends on the exogenous model parameters. For instance, stable adjustment is fast if  $\kappa$  is large, which in turn implies from (16) that marginal adjustment costs rise only slowly around the initial steady state ( $\varphi''(\rho)$  is small). Similarly, a new equilibrium will be reached quickly if the production function is strongly concave ( $\alpha$  is large), and if the depreciation rate  $\rho$  is high.

Let the time at which the policy switch occurs be denoted by  $T$ . We then have to consider two regimes in the following analysis: Regime I  $(0, T)$  describes the dynamic evolution of the capital stock and its shadow price from the announcement of the policy change in period 0 to its actual implementation in period  $T$ . Regime II  $(T, \infty)$  traces out the time path of the endogenous variables after the policy switch has been enacted. The crucial link between the two regimes is the condition that both  $\hat{k}$  and  $\hat{\mu}$  must change continuously at the time of the policy implementation, the latter since there is no new and unforeseen information at time  $T$ . This also implies that the variables  $k$  and  $\mu$  must follow an unstable path in regime I, moving away from the initial steady state equilibrium, whereas they will be on a stable path in regime II in order to reach a new steady state equilibrium in the long run.

Appendix A demonstrates in detail how to obtain expressions for the dynamic development of the capital stock and its shadow price in regimes I and II. Letting  $\hat{p}_T$  stand for the (one-time) relative change in the producer price at time  $T$ , when the switch to origin-based commodity taxation is implemented, we find for regime I

$$\hat{k}_t^I = \frac{\hat{p}_T \kappa}{\eta_1 - \eta_2} e^{-\eta_2 T} (e^{\eta_1 t} - e^{\eta_2 t}) < 0, \quad (21)$$

$$\hat{\mu}_t^I = \frac{\hat{p}_T}{\eta_1 - \eta_2} e^{-\eta_2 T} (\eta_1 e^{\eta_1 t} - \eta_2 e^{\eta_2 t}) < 0, \quad (22)$$

where the signing of the effects has used  $\eta_1 < 0, \eta_2 > 0$  from (20), and  $\hat{p}_T < 0$  for a switch to origin-based commodity taxes [eq. (15)].

In the initial steady state, the shadow price of capital  $\mu_t$  coincides with the producer price  $p_t$ . In regime I,  $p_t$  is unchanged throughout, whereas  $\mu_t$  jumps down on impact and declines further towards time  $T$ . At time  $T$ , investment goods become available at a reduced producer price due to the commodity tax switch, giving an incentive to firms to postpone investment until  $T$ .<sup>8</sup> Since capital installed right at time  $T$  competes with capital installed just before  $T$ , the latter must have a value close to the reduced producer price of capital plus installation cost at time  $T$ . At earlier dates within regime I, it is more costly to wait until the producer price falls; hence the value of the capital stock tends to be higher at dates early on in regime I than thereafter. Overall, the dynamic evolution of the shadow price of capital in regime I thus comprises a downward jump at time 0 and a gradual decline thereafter. In line with the investment function  $\psi(\mu_t/p_t)$  [cf. eq. (5)], the decline in the shadow price of capital will reduce investment below its steady-state level and lead to a reduction in the domestic capital stock between time 0 and  $T$ .

It is interesting to look in more detail at the impact change in the nominal value of the capital stock when the tax regime switch is announced at time 0. From (22) this follows by setting  $t = 0$  to give

$$\hat{\mu}_0 = \hat{p}_T e^{-\eta_2 T} < 0. \quad (23)$$

This shows that the downward jump in the nominal shadow price of capital in period 0 will be the more pronounced, the lower is the adjustment speed of investment [cf. eq. (20)] and the shorter is the time period that elapses between the announcement and the implementation of the policy switch. Only in the special case where the “lead period” is infinitely long ( $T \rightarrow \infty$ ) will the impact effect of the announcement on the shadow price of capital be negligible.

Turning to regime II ( $T, \infty$ ), we get from Appendix A

$$\hat{k}_t^{II} = \frac{\hat{p}_T \kappa}{\eta_1 - \eta_2} e^{\eta_1 t} (e^{-\eta_2 T} - e^{-\eta_1 T}) < 0, \quad (24)$$

$$\hat{\mu}_t^{II} = \hat{p}_T \left[ 1 + \frac{\eta_1}{\eta_1 - \eta_2} e^{\eta_1 t} (e^{-\eta_2 T} - e^{-\eta_1 T}) \right] < 0. \quad (25)$$

While the *nominal* shadow price of capital  $\mu_t$  does not jump at  $t = T$ , the *real* value of capital jumps upward in period  $T$  because the producer price falls at the time of the policy switch. From (25) it is seen that the reduction in  $\mu_t$  is less than the fall in the producer price, since the second term in the square bracket is negative. Since  $\mu_t = p_t$  in the initial equilibrium this must also imply that the relative co-state variable ( $\mu_t/p_t$ ) exceeds unity in

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<sup>8</sup>This indicates that the effects of an anticipated switch to origin-based commodity taxes on the optimal time path of investment are quite similar to the effects of an anticipated tax credit (cf. Nielsen and Sørensen 1991).

this regime. Hence, from (5), relative investment will exceed the depreciation rate and the capital stock gradually rise throughout regime II. The adjustment process is completed when the drop in the shadow price of the capital stock equals the percentage fall in the small country's producer price (i.e. the second term in the square bracket of (25) is zero) and the capital stock has returned to its steady state level.

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Figure 1 about here

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Figure 1 illustrates the dynamic evolution of the variables  $\mu$  and  $k$  in both regimes. The initial steady-state equilibrium is given by point  $E$ . At the time of the policy announcement, the temporary equilibrium jumps downward to point  $A$ . In regime I the system follows an unstable path until it reaches point  $B$  at time  $T$ . In regime II the system then follows the stable trajectory corresponding to the new saddlepoint equilibrium  $E_1$ .

Finally, it is easy to show that the case previously discussed in the literature (Krause-Junk 1992, Bovenberg 1994, Genser, Haufler and Sørensen 1995) is included in the present analysis as a special case. When the announcement and implementation of the switch coincide ( $T = 0$ ), then the reduction in the firm's nominal cash flow is immediately and fully capitalized in the nominal value of the capital stock [cf. eq. (23)]. However the real shadow price of capital ( $\mu/p$ ) remains constant because the producer price  $p$  falls by the same amount at time  $T = 0$ . Hence the new steady state will be reached immediately. In the absence of announcement effects, the switch to origin based commodity taxes will thus reduce the value of 'old' capital, but will not affect investment decisions and the capital stock at any point in time.

### 3.2 International Asset Accumulation

In addition to the effects on investment and production, an anticipated switch in the commodity tax regime also affects the time path of consumption. To analyze these effects we assume for simplicity, and without affecting any of the results derived, that the domestic household holds no foreign assets in the initial steady state ( $a_0 = 0$ ). International asset accumulation is driven by the equation of motion (9) and the first-order condition of the consumer's optimization problem (11). Differentiation of (11) gives

$$\hat{\lambda} \equiv \frac{d\lambda}{\lambda} = \frac{u''(c)dcq - u'(c)dq}{q^2} \frac{q}{u'(c)} = - \left[ \left( -\frac{u''(c)c}{u'(c)} \right) \hat{c} + \hat{q} \right].$$

Noting that  $\hat{q} = \hat{p}$  under the policy change considered here [cf. equation (15)] and introducing the elasticity of the marginal utility of consumption gives

$$\hat{c} = -\frac{(\hat{\lambda} + \hat{p})}{\varepsilon}, \quad \text{where } \varepsilon \equiv -\frac{u''(c)c}{u'(c)} > 0. \quad (26)$$

Linearization of (9) around the initial steady state and inserting from (2) and (14) yields in a first step

$$\dot{a} = d(\dot{a}) = rda + [kf'(k)]\hat{k} - kdh - h\hat{k} - dc.$$

Using (26),  $dh = \kappa(\hat{\mu} - \hat{p})$  from (17),  $h = \rho$  in the initial steady state and recalling that the net foreign asset position is zero initially ( $a_0 = 0$ ), this can be rewritten as

$$\dot{a} = ra + k[r\hat{k} - \kappa(\hat{\mu} - \hat{p})] + \frac{c}{\varepsilon} (\hat{\lambda} + \hat{p}). \quad (27)$$

The next step is to incorporate the regime-specific changes in  $\hat{k}$  and  $\hat{\mu}$ . As in the case of the investment path analyzed in the preceding section, the two regimes are linked by the condition that the foreign asset position  $a$  must change continuously around  $T$ . It is demonstrated in Appendix B that this requirement, together with the transversality condition (10), allows to derive an expression for the impact change in the marginal utility of wealth  $\lambda$ :

$$\hat{\lambda} = -e^{-rT} \hat{p}_T, \quad (28)$$

which is *positive* for a combined fall in producer and consumer prices at time  $T$ . From (11) this implies that the marginal utility of consumption must rise in regime I – and the level of consumption must thus fall – as a result of the policy announcement. Intuitively, an anticipated fall in the consumer price level at time  $T$  will cause households to postpone consumption until the price reduction has been realized. It is also seen from (28) that for a very distant implementation time  $T \rightarrow \infty$  we have  $\hat{\lambda} \rightarrow 0$ , so that the ‘postponement effect’ on consumption will be negligible. On the other hand, for an unanticipated switch to the origin principle ( $T = 0$ ) we have  $\hat{\lambda} = -\hat{p}$ , and the shadow price of foreign asset holdings rises by the full amount of the price change. However, since the price of consumption is simultaneously reduced to the same extent there is no change in consumption/saving behaviour. This is seen from (26), which implies  $\hat{c} = 0$  in this case. Once again, for the special case of an unanticipated switch to the origin principle, our model reproduces the neutrality result derived in earlier contributions.

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Figure 2 about here

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Figure 2 shows the time path of consumption in both regimes for the general case  $0 < T < \infty$ . In regime I, consumption is below the level that would be realized if the destination principle were maintained, or if the switch to the origin principle were not anticipated (dashed line). In regime II, households can conversely afford a higher level of consumption as a result of the increased savings made in the time interval  $(0, T)$ . Of course, *within* each regime we have the usual result that consumption smoothing is complete for



a small open economy that can borrow or lend in the international capital market at no extra cost.

Combining the dynamic effects that an anticipated switch to the origin principle has on investment and savings behaviour, we can trace out the development of the trade balance and the net foreign asset position. The trade balance in period  $t$  is equal to output minus absorption

$$TB_t \equiv f(k_t) - h_t k_t [1 + \varphi(h_t)] - c_t, \quad (29)$$

where all values are measured in international prices. If the net foreign asset position is zero initially, as we have assumed earlier, then the trade balance is also zero in the initial steady state equilibrium and  $c_0 = f(k_0) - k_0 \rho$ .

Drawing on (27), the change in the trade balance can generally be written as

$$dT B = k[r\hat{k} - \kappa(\hat{\mu} - \hat{p})] + \frac{c}{\varepsilon} (\hat{\lambda} + \hat{p}). \quad (30)$$

For regime I, using equation (B.1) in the appendix produces

$$dT B_t^I = \frac{c}{\varepsilon} \hat{\lambda} + \frac{k \kappa \hat{p}_T e^{-\eta_2 T}}{(\eta_1 - \eta_2)} [\eta_2 e^{\eta_1 t} - \eta_1 e^{\eta_2 t}] > 0, \quad (31)$$

where we have used  $\eta_1 + \eta_2 = r$  from (20). Both terms in the expression are clearly positive, indicating that in the period between the announcement and the implementation of the commodity tax switch the trade balance will unambiguously improve. Of course, this is due to the simultaneous fall in consumption and investment, which occurs in regime I.

As regards regime II, we get from equation (B.4) in the appendix

$$dT B_t^{II} = \frac{c}{\varepsilon} (\hat{p}_T + \hat{\lambda}) - \frac{k \kappa \hat{p}_T (e^{-\eta_1 T} - e^{-\eta_2 T})}{(\eta_1 - \eta_2)} \eta_2 e^{\eta_1 t} < 0. \quad (32)$$

In line with the upsurge in investment and consumption after the implementation of the tax reform at time  $T$ , the trade balance deteriorates and becomes negative. It stays below zero even in the new steady state ( $t \rightarrow \infty$ ), since the first term in (32) will be negative for any strictly positive implementation lag  $T > 0$  [cf. eq. (28)]. The interpretation of this long-run effect on the trade balance is that the improvement in the net foreign asset position during the anticipation phase will finance a permanent rise in the level of consumption.

## 4 Welfare Analysis

### 4.1 Marginal vs. non-marginal reform

This section turns to possible welfare consequences of an anticipated switch in commodity taxation from destination- to origin-based taxes. We first demonstrate that the marginal

switch which we have analyzed above is not able to influence domestic welfare when, as assumed, the economy's capital stock is entirely owned at home initially. Later we show, however, that both a non-zero foreign ownership share of domestic capital and a non-marginal tax switch will entail welfare consequences.

The welfare of the household is given by the present value of its consumption stream

$$W = \int_0^\infty e^{-rt} u(c_t) dt.$$

The change in welfare induced by the policy switch can be calculated as

$$dW = \int_0^\infty e^{-rt} u'(c_t) dc dt = \int_0^\infty e^{-rt} \frac{u'(c) c}{\varepsilon} (e^{-rT} \hat{p}_T - \hat{p}) dt,$$

where the second step has used (26) and (28). This expression must be decomposed since  $\hat{p} = 0$  in regime I, but  $\hat{p} = \hat{p}_T$  in regime II. Thus

$$\begin{aligned} dW &= \int_0^T \frac{u'(c) c \hat{p}_T}{\varepsilon} e^{-r(t+T)} dt + \int_T^\infty \frac{u'(c) c \hat{p}_T}{\varepsilon} (e^{-r(t+T)} - e^{-rt}) dt \\ &= \frac{u'(c) c \hat{p}_T}{\varepsilon} \left[ \int_0^\infty e^{-r(t+T)} dt + \int_T^\infty -e^{-rt} dt \right] = 0. \end{aligned} \quad (33)$$

Hence, in the basic model, the pre-announced switch to origin-based commodity taxation will not yield any welfare changes for the representative consumer in the small open economy. Efficiency effects are absent because a marginal policy switch will neither cause “excess” installation costs when marginal costs are zero in the initial equilibrium, nor distort the allocation of capital or the time pattern of consumption. Furthermore, redistributive effects vis-a-vis foreigners are excluded since the capital stock in the small country is assumed to be entirely owned by domestic residents and thus none of the capital losses associated with the switch to the origin regime can be shifted to foreigners.

It is easy to see, however, how foreign holdings of domestic equity capital will affect the welfare results. If  $s_F$  denotes the share of the capital stock owned by foreigners in the initial steady state, then the total value of assets owned by foreigners is  $V_F = \mu_0 s_F k_0$ . The impact effect of an announced (or anticipated) switch to the origin principle will then change the value of these assets by

$$dV_F = \hat{\mu}_0 \mu_0 s_F k_0.$$

It is straightforward to incorporate this additional effect into equation (27), which gives the change in the small country's foreign asset position. The calculations in Appendix B change accordingly, leading to a new impact change in the marginal utility of wealth  $\hat{\lambda}^*$ :

$$\hat{\lambda}^* = -e^{-rT} \hat{p}_T + \mu_0 s_F k_0 \hat{\mu}_0 \frac{\varepsilon r}{c} = -e^{-rT} \hat{p}_T \left( 1 - \mu_0 s_F k_0 \frac{\varepsilon r}{c} e^{(r-\eta_2)T} \right), \quad (34)$$

where the second step has used (23) to substitute out for  $\hat{\mu}_0$ . Comparing (28) and (34) shows that the impact change in  $\lambda$  is reduced if foreigners own part of the capital stock

initially. Intuitively, the small country's net foreign asset position improves discretely at the time of the policy announcement and this increase in lifetime income will raise consumption both before and after the switch in the commodity tax regime. In fact, it is possible now that  $\hat{\lambda}^*$  is *negative*, and hence consumption rises, despite the relatively high price of consumption in regime I. It is readily inferred from (34) that this is more likely when both the share of foreign ownership of domestic capital ( $s_F$ ) and the share of the return to capital in domestic income (and hence consumption) are high and when  $\varepsilon$  is large, implying a high preference for a smooth consumption path over time (and hence a low price elasticity of consumption). Finally, foreigners will be more effectively "expropriated" when the speed of adjustment is low due to high transaction costs (the absolute value of  $(r - \eta_2)$  is small) and when the lead period  $T$  is relatively short.

The last step is to incorporate the changed value of  $\hat{\lambda}^*$  in the welfare expression (33). This gives

$$dW^* = -u' \hat{p}_T \mu_0 s_F k_0 e^{-\eta_2 T} > 0. \quad (35)$$

Equation (35) extends the analogous formula for an unanticipated reform in Bovenberg (1994, p. 258) by pointing to the role of the time period  $T$  that elapses between the announcement and the implementation of the policy switch. In the case of a surprise tax reform ( $T = 0$ ), the adjustment speed  $\eta_2$  is irrelevant and only the extent of initial foreign ownership matters for the international distribution effect.<sup>9</sup> When the policy change is anticipated, however, the welfare changes also depend – via  $\eta_2$  – on the entire set of parameters of the investment system [cf. our previous discussion of equation (20)].

So far our analysis has been based on a marginal policy change, thus neglecting any efficiency losses that may arise from a discrete pre-announced switch to the origin principle. As a final step, we present below some simulation results for a complete, and anticipated, changeover from a destination-based to an origin-based commodity tax. To isolate the efficiency effects of this policy experiment we return to our assumption that there is no foreign ownership of domestic capital. The tax rate in the small country is assumed to be 20 %; this implies that a switch to the origin principle entails a 20 % devaluation of the domestic currency vis-a-vis the rest of the world (though not towards other union countries; cf. footnote 3). The lead period is taken to be  $T=5$ .

Our simulation experiment focuses on the role of adjustment costs for the efficiency losses involved in the policy change. Following a standard empirical specification, the adjustment cost function is assumed to be

$$\varphi(h_t) = \frac{\beta}{2} (h_t - \rho)^2,$$

where  $\beta$  is the parameter to be varied. In the empirical literature this parameter is often taken to be  $\beta = 10$  (Auerbach and Kotlikoff 1987, Fehr 1996) but we are also interested in

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<sup>9</sup>Similar redistributive effects arise in two-period models of capital taxation when there is cross-ownership of capital initially (cf. Huizinga and Nielsen 1996).

Table 1: Effects of an Anticipated Switch to the Origin Principle

transaction cost parameter $\beta$	0	10	20	$\infty$
consumption (regime I)	- 11 %	- 10 %	- 10 %	- 10 %
capital stock (at time T)	- 54 %	- 10 %	- 5 %	0
equivalent variation (in %)	- 0.97	- 0.53	- 0.47	- 0.42

$u_t = \ln(c_t), \quad f(k_t) = 3.5 k_t^{0.5}, \quad r = 0.1, \quad \rho = 0.25$

the effects of either very high or very low adjustment costs. The results of our simulation experiments are summarized in Table 1.

With the parameters selected, the announcement of the future tax reform leads to a drop in consumption of about 10 per cent (which is reversed to an increase of almost the same order upon implementation of the reform). The effects on the size of the capital stock in the small open economy at the time just prior to the implementation of the reform depend heavily on the chosen value of  $\beta$ . For the “central case” value  $\beta = 10$ , the capital stock is cut back about 10 per cent from its initial level. For very high levels of  $\beta$  it is immediately intuitive that transaction costs prohibit any temporary changes in the capital stock. At the other extreme, the complete absence of installation costs may cause a temporary outflow of capital that exceeds 50 per cent of the initial stock. In summary, we conclude that the joint effects of consumption and investment shifts will cause rather pronounced effects on the trade balance for a wide range of installation cost parameters  $\beta$ .

As regards the welfare effects (or efficiency costs) of the anticipated tax reform, they generally stem from variations in the levels of consumption and investment (and thereby the capital stock and production) before vs. after the implementation of the reform. The interesting observation is that the efficiency costs of a pre-announced switch in the tax regime are *declining* as adjustment costs rise. This result should, however, be quite intuitive given our previous finding that high installation costs dampen the inefficiency-creating swings in investment and production activity. In the extreme case of infinitely high transaction costs (and thus zero capital movements) efficiency losses arise only from a consumption distortion as the household anticipates – and responds to – the reduction in the consumer price of output after period T. More generally, our simulation results indicate that welfare losses from temporary investment distortions and excess installation costs are quite limited and – together with the costs of the consumption distortion – remain below one percent

of the benchmark utility level.

## 4.2 Discussion

The model framework we have utilized above has been kept as simple as possible to work out the fundamental effects of the commodity tax switch on the time pattern of investment and consumption. The government only had a rudimentary role in our model, raising revenue from commodity taxes and handing out the proceeds in the form of a transfer. Labour supply did not explicitly enter the model, although the production structure could be interpreted as suppressing an inflexible supply of labour. At constant rates, the commodity taxes then really were lump sum taxes, so that there were no distortions in the initial steady state. It is thus appropriate to inquire whether various changes or extensions of the model will alter our conclusions as to the macroeconomic and welfare effects of an anticipated commodity tax reform.

Instead of handing out the revenue as a transfer, the government might use it to provide public goods. With public goods entering utility, variation over time in the revenue from taxing consumption and cash flow would entail time-varying supply of public goods, which would feed back to consumption and cause it to vary *within* the two regimes. Alternatively, the government might have a fixed revenue requirement, so that the consumption and cash flow changes triggered by the announcement of a future tax reform would cause commodity tax rates to vary within regimes. These modifications of the specification of the public sector in the model will alter results, but certainly not in a fundamental way.

Potentially more significant changes in the model incorporate a labour-leisure choice, non-traded goods, and pre-existing taxes other than commodity taxes. Turning first to an endogenous labour supply decision it must be emphasized that the destination- and the origin-based commodity tax reduce the real wage of labour in essentially the same way. Hence, at the exact time of reform, the parallel changes in consumer and producer prices will ensure that the real wage does not jump. However, within regimes the variation in the stock of capital would alter wages and thereby labour supply, generating secondary welfare effects associated with variation in the consumption of leisure. Similarly, if non-traded goods were introduced, the anticipation of the tax reform would lead to a variation in the production and consumption of these goods over time, again with ramifications for welfare.

Finally, the introduction of other taxes into the model would open up the possibility that the swings in consumption and production generated by the anticipated commodity tax reform interact with existing distortions. For instance, the base of an existing savings tax would widen temporarily when the reform leads consumers to postpone their consumption. Hence, in regime I, the distortion caused by the savings tax would be counteracted by the effects of an anticipated commodity tax reform. On the other hand, after the imple-

mentation of the reform (regime II), savings would go down again, and the distortive effects of a savings tax would now be aggravated. Hence there is a tendency for these secondary welfare effects to cancel out over the two regimes. In the steady state, the level of savings – and thus the impact of a pre-existing, distortive tax on these savings – is unaffected by the temporary imbalances created by the anticipated policy switch. More generally, since both the investment and the consumption distortions caused by the commodity tax change work in different directions before and after the time of the policy implementation, we expect our aggregate welfare results to be relatively robust with respect to additional distortions or consumption wedges.<sup>10</sup>

## 5 Conclusion

Many economists have recommended that the EU switch from the current destination-based scheme of value-added taxation to an origin-based system. Whether such a switch will indeed occur in the foreseeable future is at this stage uncertain. However, it seems quite clear that if the commodity tax reform is carried out at some point, then it will have been announced and anticipated well in advance.

The literature contains several analyses of an unanticipated switch from destination-based to origin-based commodity taxes, but surprisingly there is no theoretical analysis of an *anticipated* commodity tax reform. This is what we have undertaken in the present paper. We have shown that the pre-announcement of a commodity tax reform can create significant macroeconomic effects where in the case of an unanticipated reform there would be none. Upon announcement of the tax switch, investment and consumption will drop, driving the trade balance into surplus. When the reform is finally implemented, the opposite changes in consumption and investment are registered, implying that the trade balance goes into deficit.

Despite its macroeconomic ramifications, a small anticipated switch between destination and origin taxation is unable to affect welfare. A large, anticipated commodity tax reform like that suggested for the EU, where member countries would switch from, on average, a 20 % destination-based VAT to a 20 % origin-based VAT, is able to produce welfare effects, which are associated with induced variation in consumption and investment levels before vs. after the actual implementation of the reform. Our simulation results suggest, however, that these efficiency costs may not be very sizeable, remaining below one per cent of the benchmark utility level in all the cases considered.

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<sup>10</sup>Fehr (1996) incorporates an endogenous labour supply decision and other extensions in his numerical study of commodity tax reform. While he finds that a labour-leisure choice may significantly change the redistributive effects between countries, his results with respect to the overall efficiency costs of an anticipated policy switch do support our conclusions.

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## Appendix A

Appendix A explains in detail the derivation of the dynamic development of the capital stock and its shadow price in regimes I and II. (Cf. Turnovsky (1995, pp. 137-141) for a brief introduction to the methods employed here.)

**Regime I**  $(0, T)$ : In this regime, both the stable and the unstable root are needed to describe the evolution of  $\hat{k}$  and  $\hat{\mu}$ . The general solution to the dynamic system (19) is

$$\begin{aligned}\hat{k}_t^I &= 0 + d_1 e^{\eta_1 t} + d_2 e^{\eta_2 t}, \\ \hat{\mu}_t^I &= 0 + m_0 d_1 e^{\eta_1 t} + m_0 d_2 e^{\eta_2 t},\end{aligned}\tag{A.1}$$

where  $(0, 0)$  is the equilibrium point for the dynamic system in regime I, the two eigenvalues  $\eta_1$  and  $\eta_2$  are given in (20), and  $d_1$  and  $d_2$  are the constants to be determined. The multiplier  $m_0$ , which links the multiplicative constants in the two equations, can be derived from the matrix equation  $J \times [d, m_0 d]' = 0$ . The first row of this equation determines

$$m_0 = \frac{\eta}{\kappa}.\tag{A.2}$$

At time 0 the capital stock is fixed, thus linking  $d_1$  and  $d_2$  by

$$\hat{k}_0 = d_1 + d_2 = 0 \quad \Rightarrow \quad d_2 = -d_1.\tag{A.3}$$

For the instantaneous change in  $\mu$  we get

$$\hat{\mu}_0 = d_1 \frac{\eta_1}{\kappa} + d_2 \frac{\eta_2}{\kappa} = d_1 \left( \frac{\eta_1 - \eta_2}{\kappa} \right).\tag{A.4}$$



At the time  $T$  of the actual policy implementation, the changes in the endogenous variables are given by

$$\begin{aligned}\hat{k}_T^I &= d_1 \left( e^{\eta_1 T} - e^{\eta_2 T} \right), \\ \hat{\mu}_T^I &= d_1 \left( \frac{\eta_1}{\kappa} e^{\eta_1 T} - \frac{\eta_2}{\kappa} e^{\eta_2 T} \right).\end{aligned}\tag{A.5}$$

**Regime II**  $(T, \infty)$ : The variables  $\hat{k}, \hat{\mu}$  follow a stable path in this regime and only the negative eigenvalue is needed. Thus

$$\begin{aligned}\hat{k}_t^{II} &= 0 + d_3 e^{\eta_1(t-T)}, \\ \hat{\mu}_t^{II} &= \hat{p}_T + d_3 \frac{\eta_1}{\kappa} e^{\eta_1(t-T)},\end{aligned}\tag{A.6}$$

where (A.2) has been inserted and the steady-state change in  $\mu$  must equal the change in the producer price from (4). The latter is denoted by  $\hat{p}_T$  and represents a one-time adjustment at time  $T$ , when the switch to origin-based commodity taxation is implemented. In regime II, the values of  $(\hat{k}, \hat{\mu})$  at time  $T$  are given by

$$\begin{aligned}\hat{k}_T^{II} &= d_3, \\ \hat{\mu}_T^{II} &= \hat{p}_T + d_3 \left( \frac{\eta_1}{\kappa} \right),\end{aligned}\tag{A.7}$$

We can now employ the condition that  $\hat{k}$  and  $\hat{\mu}$  must be continuous at time  $T$ . Equating  $\hat{k}_T^I = \hat{k}_T^{II}$  and  $\hat{\mu}_T^I = \hat{\mu}_T^{II}$  in (A.5) and (A.7) simultaneously determines the coefficients  $d_1$  and  $d_3$ :

$$d_1 = \frac{\hat{p}_T \kappa}{\eta_1 - \eta_2} e^{-\eta_2 T}, \quad d_3 = \frac{\hat{p}_T \kappa}{\eta_1 - \eta_2} \left[ e^{(\eta_1 - \eta_2)T} - 1 \right].$$

Inserting the coefficient  $d_1$  and (A.2)–(A.3) in (A.1) gives equations (21)–(22) for regime I. Similarly, substituting  $d_3$  in (A.6) gives equations (24)–(25) for regime II.

## Appendix B

Appendix B portrays international asset accumulation.

**Regime I**  $(0, T)$ : We substitute (21)–(22) into (27) and note that  $\hat{p}$  is still zero in this regime. The evolution of net foreign assets can then be written as

$$\dot{a}_t^I = r a_t + A_1 + A_2 \left[ (r - \eta_1) e^{\eta_1 t} - (r - \eta_2) e^{\eta_2 t} \right],\tag{B.1}$$

where

$$A_1 = \frac{c}{\varepsilon} \hat{\lambda}, \quad A_2 = \frac{k \kappa \hat{p}_T e^{-\eta_2 T}}{(\eta_1 - \eta_2)}.\tag{B.2}$$

This is a first-order differential equation with constant coefficient and variable term, where the variable term is composed of the two parts denoted by  $A_1$  and  $A_2$ . The solution to this equation is (cf. Chiang, 1984, pp. 480-482)

$$a_t^I = m_1 e^{rt} - \frac{A_1}{r} - A_2 (e^{\eta_1 t} - e^{\eta_2 t}), \quad (\text{B.3})$$

where  $A_1$  and  $A_2$  are given in (B.2) and  $m_1 = A_1/r$  is determined from the condition that  $a_0 = 0$  in the initial steady state.

**Regime II**  $(T, \infty)$ : We proceed analogously and substitute (24)–(25) into (27). This leads to the differential equation

$$\dot{a}_t^{II} = r a_t + B_1 + B_2 (r - \eta_1) e^{\eta_1 t}, \quad (\text{B.4})$$

where

$$B_1 = \frac{c}{\varepsilon} (\hat{p}_T + \hat{\lambda}), \quad B_2 = -\frac{k \kappa \hat{p}_T (e^{-\eta_1 T} - e^{-\eta_2 T})}{(\eta_1 - \eta_2)}. \quad (\text{B.5})$$

The general solution to this equation is

$$a_t^{II} = m_2 e^{rt} - \frac{B_1}{r} - B_2 e^{\eta_1 t}. \quad (\text{B.6})$$

To determine  $m_2$  we impose the condition that the foreign asset position  $a$  must change continuously around time  $T$ . Setting (B.3) and (B.6) equal for  $t = T$  and using  $m_1 = A_1/r$  gives

$$m_2 = \frac{c}{\varepsilon r} (\hat{\lambda} + e^{-rT} \hat{p}_T).$$

Substituting this in (B.6) yields

$$a_t^{II} = \frac{k \kappa \hat{p} (e^{-\eta_1 T} - e^{-\eta_2 T})}{(\eta_1 - \eta_2)} e^{\eta_1 t} + \frac{c}{\varepsilon r} [\hat{\lambda} (e^{rt} - 1) + \hat{p}_T (e^{r(t-T)} - 1)]. \quad (\text{B.7})$$

Equation (B.7) can now be used to determine the change in  $\lambda$ . This is a one-time adjustment in period 0 since we know from (12) that  $\lambda$  doesn't change over time. The missing element to pin down  $\hat{\lambda}$  is the transversality condition (10). Applying this to (B.7) gives

$$\frac{c}{\varepsilon r} (\hat{\lambda} + e^{-rT} \hat{p}_T) = 0,$$

from which equation (28) in the text follows directly.

Figure 1: The response of the capital stock and its shadow price

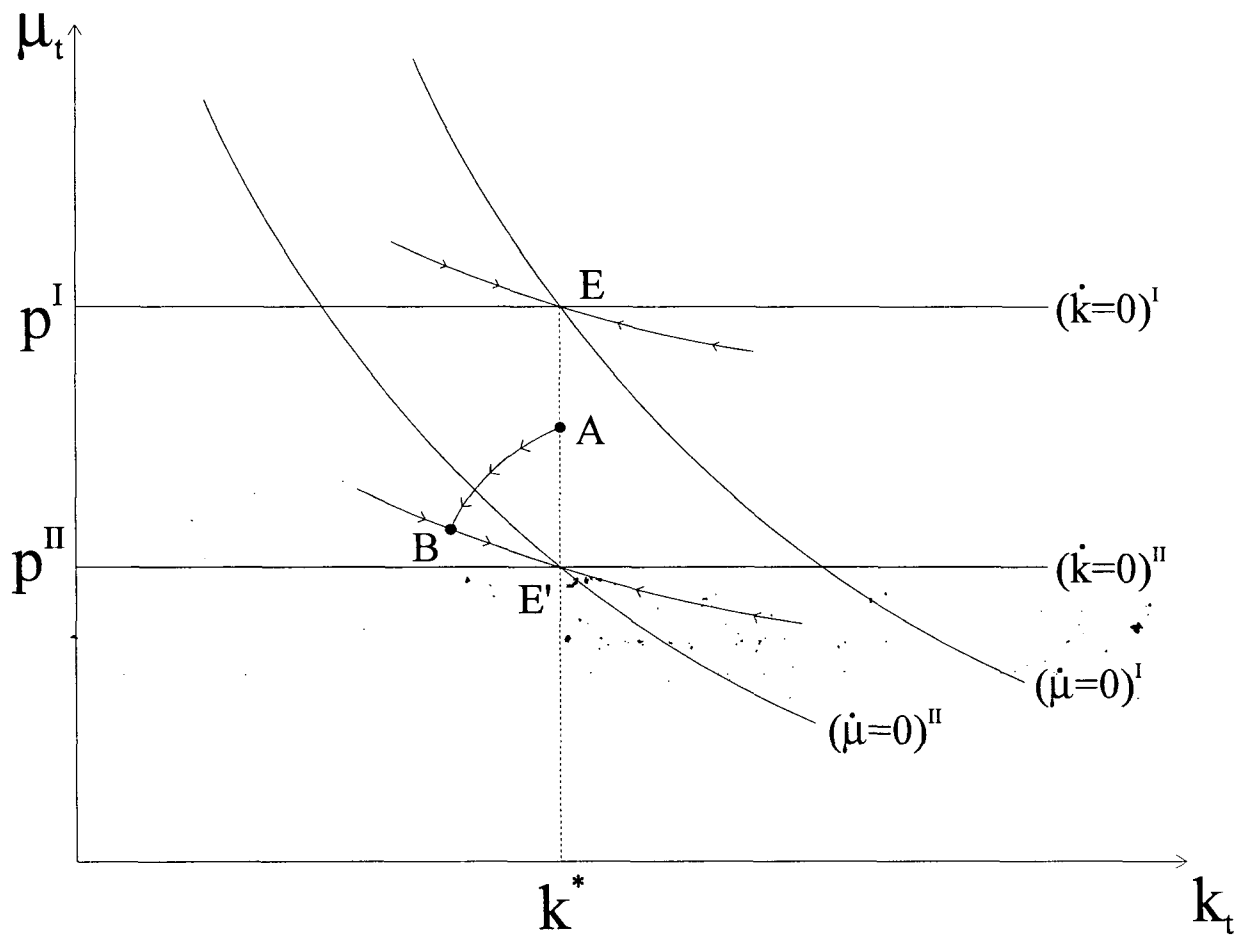


Figure 2: The response of consumption

