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MONETARY AND FISCAL POLICY IN INTERDEPENDENT ECONOMIES WITH CAPITAL ACCUMULATION, DEATH AND POPULATION GROWTH

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ABSTRACT

A two-country, optimising model with capital accumulation, purchasing power parity, floating exchange rates, uncovered interest parity, perfect foresight, finite lives and population growth is developed and analysed. For the special case of a zero birth rate, individuals are indifferent between tax-finance and bond-finance or money-finance, so that Ricardian debt-neutrality and super-neutrality prevail. The general case is analysed by decomposing the model into global averages and differences. A tax-financed increase in monetary growth leads to an interdependent Mundell-Tobin effect, that is the world real interest rate falls and capital accumulation increases. A home monetary expansion leads to an increase in home consumption, a fall in foreign consumption and an increase in home holdings of foreign assets. If the expansion occurs through open-market operations, money is super-neutral. The international spill-over effects of tax-financed and bond-financed increases in government spending and of bond-financed increases in lump-sum taxation are also considered. Numerical simulation is used to calculate the short-run multipliers and to discuss the effects of imperfect substitution between home and foreign goods.

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1. Introduction

An increase in monetary growth reduces the real interest rate and therefore increases capital and output in the long run (Tobin, 1965), hence money is not super-neutral. However, the existence of such a Tobin effect is denied in optimising models with micro foundations as then the long-run real interest rate has to match the subjective rate of time preference (Sidrauski, 1969). Obviously, non-neutralities can occur during the transient path towards long-run equilibrium (Fischer, 1979a; Asako, 1983). Long-run non-neutralities occur when money enters the production function (Dornbusch and Frenkel, 1973; Fischer, 1974), when leisure enters the utility function in a non-separable fashion (Brock, 1974), when there is population growth (Weil, 1986), or when lives are finite (van der Ploeg and Marini, 1987). This paper focusses on the last two sources of non-neutrality, which stress the disconnectedness of individuals and provide a micro foundation of the Tobin effect. It is assumed that there is a positive birth rate and absence of an intergenerational bequest motive. This means that taxes can be passed on to future (yet unborn) generations, so that debt-neutrality (Barro, 1974) and super-neutrality (Sidrauski, 1967) no longer hold.

So far, the discussion of the effects of monetary growth on the real interest rate and capital accumulation has been concerned with closed economies. In small open economies the real interest rate is pegged to the world real interest rate and therefore there is no Tobin effect. However, the world consists of interdependent economies and therefore a global Tobin effect may be relevant. In an interdependent world with floating exchange rates and perfect capital mobility, an increase in home monetary growth and inflation increases the home nominal interest rate, reduces the world real interest rate, and increases capital, output and employment, both at home and abroad. When the Central Banks care about output or consumption and inflation, one can show that in the absence of international policy coordination monetary growth and inflation are too low, real interest rates are too high, and capital, output and employment are too low (van der Ploeg, 1986). Since an increase in monetary growth is a locomotive policy, each country attempts to transfer the burden of reducing the world real interest rate to the other countries as this leads to an increase in activity without an increase in inflation. The objective of this paper is to reconsider these issues within the context of a two-country, optimising model with micro foundations, death and population growth. The advantage of such an approach is that careful account is taken of the intertemporal budget constraints of governments and private sector agents and that a more satisfactory welfare analysis is feasible.

Section 2 develops a two-country model with floating exchange rates, uncovered interest parity and perfect foresight. Individuals have uncertain lifetimes and there is population growth. The asset menu consists of home equity, home money, and home and foreign government bonds. Section 3 considers the special case of a zero birth rate, which occurs when agents have infinite lives and when there is no population growth. For this case any increase in non-human wealth, due to an increase in government debt, is exactly off-set by a reduction in human wealth, arising from the future taxes required to pay off the additional government debt, hence Ricardian debt-neutrality prevails. Similarly, individuals are indifferent between money-finance and tax-finance and therefore super-neutrality holds. Section 4 decomposes the general two-country model into global averages and global differences, which simplifies the analysis considerably. Section 5 considers joint and unilateral increases in monetary growth. When the residual mode of government finance is lump-sum taxation, one has an interdependent Mundell-Tobin effect. However, when the increase in monetary growth occurs through open-market operations, money is super-neutral. The effects of a home, tax-financed increase in monetary growth are a fall in the world real interest rate, an increase in global activity, an increase in home consumption, a fall in foreign consumption, an increase in home holdings of foreign assets, and a home balance-of-trade deficit. Section 6 considers joint and unilateral increases in government spending, both when they are tax-financed and when they are bond-financed, and Section 7 considers joint and unilateral bond-financed increases in lump-sum taxation. Section 8 generalises the model to allow for imperfect substitution between home and foreign goods and uses numerical simulation to compare the results with those under purchasing power parity. Section 9 concludes the paper.

2. A Two-country model with capital, money and government debt

2.1 Finite lives and the individual's demand for goods and money balances

The demand side of each economy is made up of identical consumers with constant life expectancy. There is no intergenerational bequest motive, as in the analysis of Blanchard (1985) and of Weil (1986). The supply of labour at time t of a consumer born at time $s \leq t$, $\ell(s,t)$, is inelastic, say $\ell(s,t) = 1$. The consumer has Cobb-Douglas preferences over the consumption of private goods, $c(s,t)$, real money balances, $m(s,t)$, and the consumption of public goods, $g(t)$, and has an intertemporal elasticity of substitution of unity. Feenstra (1986) provides a justification, based on liquidity costs, for entering money in the utility function. The consumer faces the following optimisation problem:

$$\underset{c,m}{\text{Max},} \int_t^{\infty} \log\{[c(s,v)^{\gamma}m(s,v)^{1-\gamma}]g(v)^{\gamma'}\}\exp[(\alpha+\beta)(t-v)]dv, \quad 0 < \gamma < 1 \tag{2.1}$$

subject to the individual consumer's flow budget constraint,

$$\frac{da(s,t)}{dt} = [r(t) + \beta]a(s,t) + w(t)\ell(s,t) - z(s,t) - c(s,t) - [r(t) + p(t)]m(s,t), \tag{2.2}$$

and the condition precluding Ponzi games,

$$\lim_{v\to\infty} \exp\{-\int_t^v [r(\mu) + \beta]d\mu\}a(v,t) = 0, \tag{2.3}$$

where α denotes the subjective rate of time preference, β denotes the constant instantaneous probability of death, $w(t)$, $r(t)$ and $p(t)$ denote the real wage, the real interest rate and the inflation rate at time t, respectively, and $c(s,t)$, $m(s,t)$, $a(s,t)$ and $z(s,t)$ denote the consumption of goods, the holdings of real money balances, real non-human wealth and lump-sum taxation at time t of a consumer born at time s, respectively. The individual consumer receives (pays), for every period of his life, a premium, $\beta a(s,t)$, and at the time of death the individual's net wealth (debt) goes to (is cancelled by) the life insurance company. The premium is actuarially fair, so that this formulation corresponds to efficient life insurance or annuities market. Equation (2.3) ensures that the individual does not run up an indefinite debt. Since the probability of death is β, the subjective rate of time preference and the real rate of return are effectively increased by this amount.

Total consumption, $u(s,t)$, consists of consumption of goods plus interest foregone on money holdings, that is

$$u(s,t) \equiv c(s,t) + [r(t) + p(t)]m(s,t). \tag{2.4}$$

The optimisation then yields $c(s,t) = \gamma u(s,t)$, $m(s,t) = (1-\gamma)u(s,t)/[r(t) + p(t)]$ and the "tilt" of the total consumption function, $du(s,t)/dt = [r(t) - \alpha]u(s,t)$. Note that the individual consumer ensures that the marginal rate of substitution between goods and real money balances equals the opportunity cost of holding real money balances, i.e., the nominal interest rate, and that the elasticity of money demand with respect to the nominal interest rate is unity. If one defines human wealth as the present discounted value of after-tax wage income,

$$h(s,t) \equiv \int_t^{\infty} [w(v)\ell(s,v) - z(s,v)]\exp\{-\int_t^{v} [r(\mu) + \beta]d\mu\}dv \tag{2.5}$$

where the discount rate equals the real interest rate plus the probability of death, one can write total consumption as

$$u(s,t) = (\alpha+\beta)[a(s,t) + h(s,t)]. \tag{2.6}$$

The consumption function is linear in human plus non-human wealth, because the intertemporal elasticity of substitution is assumed to be unity. This assumption facilitates the aggregation across individuals born at the same instant. Blanchard (1985) discusses the implications of general iso-elastic utility functions for non-monetary economies.

2.2 Aggregation across individuals and population growth

Buiter (1986) extends the aggregation procedure of Yaari (1965) and Blanchard (1985) to allow for population growth and extends the aggregation procedure of Weil (1986) to allow for finite lives. This extension allows for overlapping families of finitely-lived individuals and is applied here.

At each instant a new cohort is born. The size of each cohort grows at a constant rate, so that the size of the cohort born at time t equals $(n+\beta)\exp(nt)$, where n denotes the constant rate of population growth. The size at time t of the surviving cohort born at time $s \leq t$ equals $(n+\beta)\exp(ns)\exp[-\beta(t-s)]$, since β is the probability of death. The total population at time t equals $(n+\beta)\int_{-\infty}^{t} \exp(ns)\exp[-\beta(t-s)]ds = \exp(nt)$. The per-capita population aggregate for, say, total consumption, is defined as

$$U(t) \equiv (n+\beta)\int_{-\infty}^{t} u(s,t)\exp[(n+\beta)(s-t)]ds, \tag{2.7}$$

because the population aggregate is obtained as the sum of the total consumption of all surviving cohorts at time t, $u(s,t)$, $s \leq t$, times the size of the surviving cohort, $(n+\beta)\exp(ns)\exp[-\beta(t-s)]$ and the per-capita population aggregate is obtained by dividing the population aggregate by the population size, $\exp(nt)$. Other per-capita population aggregates are obtained in a similar manner and are denoted by a capital letter,

Application of this aggregation procedure yields:

$$C(t) = \gamma U(t) \tag{2.8}$$

$$M(t) = (1-\gamma)U(t)/[r(t) + p(t)] \tag{2.9}$$

$$\dot{U}(t) = [r(t) - \alpha]U(t) - (n+\beta)(\alpha+\beta)A(t) \tag{2.10}$$

$$\dot{A}(t) = [r(t) - n]A(t) + w(t) - Z(t) - U(t) \tag{2.11}$$

The derivation of (2.11) used the fact that, in the absence of bequests, the non-human wealth of newly born individuals must be zero, $a(t,t) = 0$. Unlike (2.2), (2.11) no longer contains a life-insurance premium as they effectively constitute a transfer from those who die to those who survive and therefore they do not affect the return on aggregate non-human wealth. Aggregation of human wealth, (2.5), yields $\dot{H} = (r+\beta)H - w + Z$. Upon substitution of this and the aggregate consumption function, $U = (\alpha+\beta)(A+H)$, into (2.11), one obtains the "tilt" of the aggregate consumption function, (2.10).

2.3 Production

The production side of each economy follows from a concave and twice differentiable constant-returns-to-scale production function, $y(t) = \bar{f}(k(t),\ell(t))$ where $y(t)$, $k(t)$ and $\ell(t)$ denote aggregate production, the capital stock and employment at time t, respectively. The value of the firm, v, follows from the condition for risk-neutral arbitrage between equity and other financial assets, that is $rv = \dot{v}^e + (y - w\ell - i)$ where i denotes gross investment. Hence, shareholders equate the return on equity, i.e., capital gains plus dividends, to the real return on alternative assets. Integration of this arbitrage condition gives an expression for the value of the firm,

$$v(t) = \int_t^\infty [\bar{f}(k(v), \ell(v)) - w(v)\ell(v) - i(v)]\exp[-\int_t^v r(\mu)d\mu]dv \qquad (2.12)$$

which simply represents the present discounted value of future profits. Maximisation of the value of the firm subject to the capital accumulation condition, $\dot{k} = i - \delta k$ where δ denotes the depreciation rate, yields $\bar{f}_\ell(k,\ell) = w$ and $\bar{f}_k(k,\ell) = r + \delta$. In other words, the marginal product of labour equals the real wage and the marginal product of capital equals the user cost of capital, i.e., the rental charge plus depreciation charge minus capital gains. There are no adjustment costs associated with investment, so that Tobin's "Q" is unity and therefore $v = k$. Labour market equilibrium gives $\ell(t) = \exp(nt)$. In per-capita units, one has $f'(K) = r$, $f(K) - Kf'(K) = w$ and $\dot{K} = I - (\delta+n)K$, $K(0) = K_0$, where $K(t) \equiv k(t)\exp(-nt)$, $I(t) \equiv i(t)\exp(-nt)$ and net per-capita output is given by $f(K) \equiv \bar{f}(K,1) - \delta K$.

The excess of net output over wages plus dividends, $\Pi \equiv \bar{f}(K,1) - w - I$, must equal the capital gains on equity, that is $f - \Pi - w = \dot{V}^e + nV$. Since $f(K) = rK + w$, one has $\Pi + \dot{V}^e = (r - n)V$.

2.4 Financial assets and the government budget constraint

The asset menu of consumers consists of home cash, home government bonds, foreign government bonds and home (and foreign) equity. Since home equity, home government bonds and foreign government bonds are perfect substitutes, the results also hold for the case when there is international trade in equities. Hence, there is no currency substitution and money can be treated as a non-traded good. Home and foreign government bonds are perfect substitutes, so that non-human wealth corresponds to $A \equiv M+B+V$ where B denotes the per-capita holdings of home and foreign government bonds by home individuals. The government spends on goods, levies lump-sum taxes and finances the deficit by printing money or issuing government debt. This is captured by the government budget constraint,

$$\dot{D} = (r-n)D + G - Z - \theta M, \quad D(0) = D_0 \qquad (2.13)$$

where $D(t)$ denotes the per-capita government debt issued to home and foreign individuals at time t, $G(t) = g(t)\exp(-nt)$ denotes per-capita government spending at time t and $\theta(t)$ denotes the growth rate of the aggregate nominal money supply. Seignorage revenues are represented by the term θM. Integration of (2.13) and application of the solvency (no Ponzi games) condition yields

$$D(t) = \int_t^{\infty} [Z(v) + \theta(v)M(v) - G(v)]\exp\{-\int_t^{v} [r(\mu) - n]d\mu\}dv, \tag{2.13'}$$

so that the current real government debt has to be paid off by the present discounted value of the excess of future lump-sum taxes and seignorage revenues over government spending. Note that finite lives and population growth drive a wedge between the discount rate used to calculate government debt, $r - n$, and the discount rate used to calculate human wealth, $r + \beta$.

Equilibrium in the money market is represented by

$$\dot{M} = (\theta - p - n)M, \quad M(0) = \text{free}. \tag{2.14}$$

Since the economies are classical without any rigidities, the price level clears the goods markets and depends on expected future events. This implies that the initial price level and the initial per-capita holdings of real money balances, $M(0)$, are free to jump.

Each government has four policy instruments, viz., G, Z, θ and D, of which three can be chosen freely and the fourth follows residually from the government budget constraint. Under bond-finance it is assumed that G and θ are exogeneous policy instruments, Z is an endogeneous policy instrument and follows from a feedback rule, and D follows from the government budget constraint. A feedback rule for lump-sum taxation is required, because in the absence of such a rule the solvency of the government is not ensured and therefore the government debt explodes. A sensible tax rule is

$$Z = \xi_0 - \xi_1\dot{D} + \xi_2 D, \qquad (2.15)$$

so that taxes are raised when the real government debt is high or when there is a government surplus. Solvency usually requires $\partial\dot{D}/\partial D = (r-n-\xi_2)/(1-\xi_1) < 0$, so that either $\xi_2 > r - n$ and $\xi_1 = 0$ or $\xi_2 = 0$ and $\xi_1 > 1$ is assumed. Note that, for $\xi_2 = 0$, a long-run increase in taxation, ξ_0, is preceded by a short-run cut in taxation, $Z = \{- \xi_0 + \xi_1[(r-n)D + G - \theta M]\}/(\xi_1-1)$. Obviously, an increase in government spending or fall in seignorage revenues requires an increase in taxation. The case of tax-finance $(\dot{D}=0)$ corresponds to $\xi_1 \to \infty$, so that $Z = (r-n)D_0 + G - \theta M$. From now on, it will be assumed that the tax rule is given by $Z = \xi_0 - \xi_1\dot{D}$ (i.e., $\xi_2 = 0$). Note that only the aggregate level of lump-sum taxes matters for the aggregate per-capita variables, so that the distribution of taxes across generations does not affect aggregate per-capita variables.

2.5 The international context

The world consists of two economies with identical preferences, technologies and demographic structures. The foreign country has similar relationships to the ones discussed in Sections 2.1-2.4 and its variables are denoted by an asterisk. There is no labour mobility between the two countries and there is no international market for equity. However, there are efficient international markets for goods and government bonds. In fact, it is assumed that there is perfect substitution between home and foreign products as well as between home and foreign government bonds. Hence, (relative) purchasing power parity, $p(t) = p^*(t) + e(t)$ where $e(t)$ denotes the rate of depreciation of the nominal exchange rate at time t, and uncovered interest parity, $r(t) + p(t) = r^*(t) + p^*(t) + e^e(t)$, must hold. Together with the assumption of perfect foresight, one has equalisation of real interest rates, $r(t) = r^*(t)$. It follows from $f'(K) = f'(K^*) = r$

that the home and foreign capital stocks must also be the same, $K = K^*$, and that therefore wage rates must be the same, $w = w^*$.

The "law of one price" implies that there is a world market for goods for which the equilibrium condition is

$$Y + Y^* = C + C^* + I + I^* + G + G^*, \tag{2.16}$$

where $Y = \bar{f}(K,1)$ denotes per-capita gross output. Net holdings of foreign assets are the excess of private sector agents' holdings of bonds over government debt, that is $F \equiv B - D$. The condition for equilibrium in the world market for government bonds is $B + B^* = D + D^*$, which implies that $F^* = - F$. The balance of trade is the excess of domestic production over domestic absorptions, $Y - C - I - G$. Together with interest on net foreign assets it gives the current account,

$$\dot{F} = (r-n)F + Y - C - I - G, \quad F(0) = F_0, \tag{2.17}$$

which equals the increase in wealth of the nation. Note that subtraction of $\dot{K} = I - (\delta+n)K$, (2.13) and (2.14) from (2.11) yields (2.17). Integration of (2.17) and application of the country's solvency (no Ponzi games) condition gives

$$F^*(t) = \int_t^{\infty} [Y(v) - C(v) - I(v) - G(v)]\exp\{- \int_t^{v} [r(\mu) - n]d\mu\}dv, \tag{2.17'}$$

so that the current debt of the nation eventually has to be paid off by future savings' surplusses of the government and private sector (i.e., by future balance-of-trade surplusses).

2.6 The complete model

The complete two-country model can be summarised by eight nonlinear ordinary differential equations in terms of eight state-space variables, viz., the per-capita capital stock, net foreign assets, total consumption at home and abroad, real money balances at home and abroad, and real government debt at home and abroad:

$$\dot{K} = f(K) - nK - \tfrac{1}{2}\gamma(U+U^*) - \tfrac{1}{2}(G+G^*), \quad K(0) = K_0 \tag{2.18}$$

$$\dot{F} = [f'(K) - n]F + \tfrac{1}{2}\gamma(U^*-U) + \tfrac{1}{2}(G^*-G), \quad F(0) = F_0 \tag{2.19}$$

$$\dot{U} = [f'(K) - \alpha]U - (n+\beta)(\alpha+\beta)(K+M+D+F), \quad U(0) = \text{free} \tag{2.20}$$

$$\dot{U}^* = [f'(K) - \alpha]U^* - (n+\beta)(\alpha+\beta)(K+M^*+D^*-F), \quad U^*(0) = \text{free} \tag{2.21}$$

$$\dot{M} = [f'(K) + \theta - n]M - (1-\gamma)U, \quad M(0) = \text{free} \tag{2.22}$$

$$\dot{M}^* = [f'(K) + \theta^* - n]M^* - (1-\gamma)U^*, \quad M^*(0) = \text{free} \tag{2.23}$$

$$\dot{D} = \{[f'(K) - n]D + G - \xi_0 - \theta M\}/(1-\xi_1), \quad D(0) = D_0 \tag{2.24}$$

$$\dot{D}^* = \{[f'(K) - n]D^* + G^* - \xi_0^* - \theta^* M^*\}/(1-\xi_1), \quad D^*(0) = D_0^*. \tag{2.25}$$

The development of the eight state-space variables depends on the paths taken on by the exogeneous policy instruments, viz., θ, θ^*, G, G^*, ξ_0 and ξ_0^*. All other variables follow from the eight state-space variables and the six exogeneous policy instruments: $Y = f(K) + \delta K$, $C = \gamma U$, $I = f(K) + \delta K - \tfrac{1}{2}\gamma(U+U^*) - \tfrac{1}{2}(G+G^*)$, $Z = \xi_0 - \xi_1\dot{D}$, $r = f'(K)$, $w = f(K) - Kf'(K)$, $p = (1-\gamma)(U/M) - f'(K)$, $B = D + F$, $A = K + M + D + F$ and $H = U(\alpha+\beta)^{-1} - K - M - D - F$.

In summary, the above presented a two-country model with finite lives, population growth, an asset menu consisting of money, capital and bonds, purchasing power parity, uncovered interest parity, floating exchange rates, labour immobility, inelastic supply of labour, full employment, perfect foresight, and Cobb-Douglas preferences.

3. Super-neutrality and debt-neutrality

Since the death rate is β and the population growth rate is n, the birth rate must equal $n + \beta$. The birth rate is exactly the wedge between the discount rate used to calculate human wealth, $r + \beta$, and the discount rate used to calculate the government debt, $r - n$. If the birth rate is zero, this wedge is zero and therefore it is no longer possible for society to pass taxes on to future generations. This implies that individuals are indifferent between tax-finance and bond-finance of the government deficit, because an increase in government debt has to be paid off by future taxes and the discounted value of these taxes reduces human wealth by exactly the same amount as non-human wealth is increased. Hence, Ricardian debt-neutrality (cf., Barro, 1974) prevails when the birth rate is zero.

For a zero birth rate, one has $U = U^*$,

$$\dot{K} = f(K) - nK - \gamma U - \tfrac{1}{2}(G+G^*), \quad K(0) = K_0, \tag{3.1}$$

$$\dot{F} = [f'(K) - n]F + \tfrac{1}{2}(G^*-G), \quad F(0) = F_0 \tag{3.2}$$

and

$$\dot{U} = [f'(K) - \alpha]U, \quad U(0) = \text{free}. \tag{3.3}$$

Clearly, increases in monetary growth (induced by open market operations) at home or abroad (θ, θ^*) have no effect on the real interest rate, capital, output, consumption of goods or investment and therefore super-neutrality (cf., Sidrauski, 1967) holds. They increase the inflation and nominal interest rates one-for-one and thus reduce holdings of real money balances, so that economic welfare falls. Real seignorage revenues increase (see equation (5.4)), which permits the servicing of a greater government debt as lump-sum taxes are unaffected. In fact, the fall in non-human wealth, caused by the fall in real money balances, is exactly off-set by the increase in non-human wealth, caused by the increase in holdings of bonds, so that total wealth and consumption are unaffected. Super-neutrality of monetary growth also holds when lump-sum taxes rather than bonds are the residual mode of government finance. In that case, the fall in non-human wealth is exactly off-set by the increase in human wealth, caused by the fall in lump-sum taxes.

It is easy to show that, for a zero birth rate, $dK(\infty)/dG = dK^*(\infty)/dG = 0$, $dC(\infty)/dG = dC^*(\infty)/dG = -\frac{1}{2}$ and $dF(\infty)/dG = \frac{1}{2}/(\alpha - n)$, so that any increase in real government spending is completely crowded out by a reduction in private consumption and therefore has no effect on the real interest rate, capital stock or output. The associated trade deficits imply a transient foreign debt, but in the long run must be associated with net foreign assets (if $n < \alpha$). More importantly, the transient and steady-state effects of government spending on capital, output and consumption do not depend on whether it is financed by money, bonds or taxes. Bond-finance today is not perceived as an increase in private sector wealth, because the discounted value of the future lump-sum or inflation taxes required to pay off the debt exactly equals today's increase in government debt. It is also obvious that, when the birth rate is zero, changes in lump-sum taxation have no real effects.

Note that the death rate is irrelevant for these neutrality results. For example, economies with a positive death rate and a zero birth rate ($\beta = -n > 0$) have a declining population and are characterised by super-neutrality and debt-neutrality.

In the light of the above discussion, it may be useful to relate the two-country model presented in Section 2 to some previous models. If one assumes zero population growth, infinite lives and no government debt ($n = \beta = D = D^* = 0$), the present model corresponds to a two-country extension of the money-capital, closed-economy model developed by Sidrauski (1967). In such a world long-run super-neutrality holds, that is, monetary growth is unable to affect the steady-state outcomes of real variables, even though (for weakly non-separable rather than Cobb-Douglas preferences) there may be short-run neutralities (Fischer, 1979b; Asako, 1983). If one assumes zero population growth, finite lives and no government debt ($n = D = D^* = 0$), the present model corresponds to a two-country extension of the closed-economy model developed by Marini and van der Ploeg (1987). In that case, an increase in monetary growth with lump-sum taxes as the residual mode of government finance reduces the real interest rate, increases capital, increases seignorage revenues and therefore reduces lump-sum taxes by the same amount, increases both human and total wealth, and increases the consumption of goods. Finite lives clearly destroys the super-neutrality result. Similarly, an increase in government spending increases the interest rate, reduces capital, real money balances, human wealth and non-human wealth, increases lump-sum taxation, reduces seignorage revenues, and leads to more than 100% crowding out of private consumption. If one assumes positive population growth and infinite lives ($\beta = 0$), the present model corresponds to a two-country extension of the closed-economy developed by Weil (1986). Weil finds that population growth alone is sufficient to destroy the long-run superneutrality of monetary growth. The reason is, of course, that the government can tax both those individuals currently alive and those individuals yet to be born. In fact, it has already been argued above that a necessary and sufficient condition for super-neutrality is that the total birth rate is zero.

Blanchard (1985) shows, for a closed economy without money and capital, that finite lives destroy Barro's (1974) result for Ricardian debt-neutrality and Weil (1986) shows the same for population growth. Buiter (1986) shows, for a closed economy without money and capital, that a necessary and sufficient condition for Ricardian debt-neutrality is that the total birth rate, i.e., the sum of the population growth rate and the probability of death, must be zero.

4. Global averages and global differences

From now on the world of super-neutrality and debt-neutrality is abandoned in favour of a world with strictly positive birth rates. This involves the full system (2.18)-(2.25). However, as long as the nonlinear system (2.18)-(2.25) is linearised around a symmetric steady state (around $\theta = \theta^*$ and $G = G^*$), it can be decoupled into a sub-system for the global averages and into another sub-system for the global differences (cf., Aoki, 1981).

The state-space vector of global averages is $\underset{\sim}{x}^a \equiv (K^a, U^a, M^a, D^a)'$ and the instrument vector of global averages is $\underset{\sim}{u}^a \equiv (\theta^a, G^a, \xi_0^a)'$, where a global average is defined as the deviation of the arithmetic average of the home and foreign level from its steady-state level ($K^a \equiv K - K(\infty)$ and, say, $U^a \equiv \frac{1}{2}[U - U(\infty)] + \frac{1}{2}[U^* - U^*(\infty)]$). The linearised sub-system for the global averages can then be written as

$$\dot{\underset{\sim}{x}}^a = \left(\begin{array}{c|c|c|c} r-n & -\gamma & 0 & 0 \\ \hline Uf''-(n+\beta)(\alpha+\beta) & r-\alpha & -(n+\beta)(\alpha+\beta) & -(n+\beta)(\alpha+\beta) \\ \hline Mf'' & -(1-\gamma) & r+\theta-n & 0 \\ \hline -Df''\xi & 0 & \theta\xi & -(r-n)\xi \end{array}\right) \underset{\sim}{x}^a + \left(\begin{array}{c|c|c} 0 & -1 & 0 \\ \hline 0 & 0 & 0 \\ \hline M & 0 & 0 \\ \hline M\xi & -\xi & \xi \end{array}\right) \underset{\sim}{u}^a$$

$$= A^a \underset{\sim}{x}^a + B^a \underset{\sim}{u}^a, \qquad (4.1)$$

where $\xi \equiv 1/(\xi_1-1) > 0$. The sub-system of global averages, (4.1), corresponds to the description of a closed world economy and therefore issues such as current-account dynamics do not feature. The saddlepoint property (e.g., Buiter, 1984) of this perfect foresight sub-system requires two eigenvalues with negative real parts and two eigenvalues with positive real parts corresponding to two backward-looking (predetermined) variables, K^a and D^a, and two forward-looking (jump) variables, U^a and M^a, respectively. The product of the four eigenvalues associated with the sub-system of global averages equals

$$\Delta^a \equiv \det(A^d) = \{-(r-n)\Delta^a_{TF} + (n+\beta)(\alpha+\beta)[(r-n)(1-\gamma)\theta - \gamma f''(\theta M + (r+\theta-n)D)]\}\xi,$$

where the product of the three eigenvalues[1] associated with the sub-system for the case of tax-finance $(\xi \to 0,\ \dot{D}^a = 0)$ is given by

$$\Delta^a_{TF} \equiv \gamma(r+\theta-n)Uf'' + (n+\beta)(\alpha+\beta)\{\gamma Mf'' + (1-\gamma)[\theta - (w-Z)/M]\}.$$

Upon substitution of Δ^a_{TF} into Δ^a, one obtains

$$\Delta^a = -\xi\{\gamma(r-n)(r+\theta-n)Uf'' + (n+\beta)(\alpha+\beta)[\gamma f''(r+\theta-n)(D+M) - (r-n)(1-\gamma)(w-Z)/M]\} > 0$$

which is consistent with the saddlepoint property (given that $r - n > 0$ is assumed to hold).[2]

The state-space vector of global differences is $\underset{\sim}{x}^d \equiv (F, U^d, M^d, D^d)'$ and the instrument vector of global differences is $\underset{\sim}{u}^d \equiv (\theta^d, G^d, \xi_0^d)$, where

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1 The fourth eigenvalue is 0.

2 It is possible to examine under which conditions the saddlepoint property holds for the special case of tax-finance. It will be assumed that wage income is sufficient to cover lump-sum taxes plus the interest foregone on holding real money balances (i.e., $w > Z + (r+\theta-n)M$), so that Δ^a_{TF} is negative. Hence, the tax-finance system has either one stable and two unstable eigenvalues or three stable eigenvalues. Since the sum of the eigenvalues, $r - n + r - \alpha + r + \theta - n$, is positive (as $n < r \leq \alpha + \beta + n$ is assumed to hold), the second possibility is ruled out and therefore the saddlepoint property is satisfied.

a global difference is defined as the arithmetic difference of the home and foreign level from its steady-state level (e.g., $U^d \equiv [U - U(\infty)] - [U^* - U^*(\infty)]$). The linearised sub-system for the global differences can then be written as

$$\dot{\underset{\sim}{x}}^d = \begin{pmatrix} r-n & -\tfrac{1}{2}\gamma & 0 & 0 \\ -2(n+\beta)(\alpha+\beta) & r-\alpha & -(n+\beta)(\alpha+\beta) & -(n+\beta)(\alpha+\beta) \\ 0 & -(1-\gamma) & r+\theta-n & 0 \\ 0 & 0 & \theta\xi & -(r-n)\xi \end{pmatrix} \underset{\sim}{x}^d + \begin{pmatrix} 0 & -\tfrac{1}{2} & 0 \\ 0 & 0 & 0 \\ M & 0 & 0 \\ M\xi & -\xi & \xi \end{pmatrix} \underset{\sim}{u}^d$$

$$= A^d \underset{\sim}{x}^d + B^d \underset{\sim}{u}^d. \qquad (4.2)$$

The sub-system of global differences, (4.2), does not depend on global activity variables, so that the current-account dynamics and the capital-stock dynamics are decoupled and can therefore be analysed separately. The saddlepoint property requires two eigenvalues with negative real parts, associated with the predetermined variables, F and D^d, and two eigenvalues with positive real parts, associated with the jump variables, U^d and M^d. The product of the four eigenvalues associated with the sub-system of global differences equals

$$\Delta^d \equiv \det(A^d) = \{-(r-n)\Delta^d_{TF} + (n+\beta)(\alpha+\beta)(r-n)(1-\gamma)\theta\}\xi = (n+\beta)(\alpha+\beta)(1-\gamma)(r-n)(w-Z)\xi/M \geq 0$$

where the product of the three eigenvalues associated with the sub-system for the case of tax-finance is given by

$$\Delta^d_{TF} \equiv -(n+\beta)(\alpha+\beta)(1-\gamma)[-\theta + (w-Z)/M] \leq 0,$$

which is consistent with the saddlepoint property.

The comparative statics of the steady state makes use of $d\underset{\sim}{x}^a(\infty)/d\underset{\sim}{u}^a = -(A^a)^{-1}B^a$ and $d\underset{\sim}{x}^d(\infty)/d\underset{\sim}{u}^d = -(A^d)^{-1}B^d$, so that

$$d\underset{\sim}{x}(\infty)/d\underset{\sim}{u} = -\tfrac{1}{2}[(A^a)^{-1}B^a + (A^d)^{-1}B^d] \qquad (4.3)$$

and

$$dx^*(\infty)/du = -\tfrac{1}{2}[(A^a)^{-1}B^a - (A^d)^{-1}B^d]. \qquad (4.4)$$

These expressions for the steady-state multipliers can be evaluated analytically with the aid of Cramer's rule (see Sections 5-7). Although the comparative dynamics can, in principle, be evaluated analytically, it is cumbersome and therefore dynamic adjustment paths for the endogeneous variables are evaluated numerically. The transient perfect-foresight trajectories of the linearised model will be calculated with the aid of Buiter's (1984) method of spectral decomposition (and the computer program of Austin and Buiter (1982)). It is easy to show that the impact effects on the jump variables are, for the global averages, given by

$$x_j^a(0) \equiv \begin{pmatrix} U^a \\ M^a \end{pmatrix} = -N_{jj}^{-1}\Lambda_j^{-1}(N_{jp}N_{jj})JB^a u^a, \qquad (4.5)$$

where Λ_j is a diagonal matrix with the two eigenvalues with positive real roots of A^a as its elements, $(N_{jp} \mid N_{jj})$ is a matrix whose rows contain the row-eigenvectors associated with the two eigenvalues in Λ_j, and J is a matrix of zeroes and ones that permutes the second and fourth row of $B^a u^a$. A similar expression is used for the jumps in the global differences. The parameter values that will be used and the implied eigenvalues are presented in Table 1. It is clear that the eigenvalues of (4.1) and (4.2) under tax-finance $(\xi=0)$ are real and satisfy the saddlepoint property. The global averages take about 35 time units $(-[\ln(0.001)/0.1991])$ whereas the global differences take about 253 time units to settle down within 0.1% of the steady-state values. The slow adjustment of the global differences is mainly due to the sluggish nature of the current-account dynamics.

5. Monetary policy

5.1 Steady-state effects of a joint increase in monetary growth

The case of tax-finance is considered first. The relevant steady-state, tax-financed multipliers for multilateral increases in monetary growth are given by:

$$[dK^a(\infty)/d\theta^a]_{TF} = -(n+\beta)(\alpha+\beta)\gamma M/\Delta^a_{TF} \geq 0 \tag{5.1}$$

$$[dU^a(\infty)/d\theta^a]_{TF} = -(n+\beta)(\alpha+\beta)(r-\pi)M/\Delta^a_{TF} \geq 0 \tag{5.2}$$

$$[dM^a(\infty)/d\theta^a]_{TF} = -M\{\gamma Uf'' - (n+\beta)(\alpha+\beta)[((w-Z)/U) - (1-\gamma)]\}/\Delta^a_{TF}$$

$$(\leq -\gamma MUf''/\Delta^a_{TF} < 0), \tag{5.3}$$

so that $[dr(\infty)/d\theta^a]_{TF} = -(n+\beta)(\alpha+\beta)\gamma Mf''/\Delta^a_{TF} \leq 0$. Hence, as long as the total birth rate is positive, a joint increase in monetary growth leads in the long run to a one-for-one increase in inflation, an increase in nominal interest rates, a fall in the world real interest rate, increases in global capital, output and consumption of goods, and a fall in real money balances. These multipliers remind one of the conventional Mundell-Tobin effect, yet they are derived from a general equilibrium model with micro foundations. This break-down of super-neutrality arises, because a positive birth rate drives a wedge between the discount rate used to calculate human wealth and the one used to calculate government debt and therefore drives a wedge between the real interest rate and the rate of time preference.

The steady-state effect on real seignorage revenues is given by

$$[d\theta^a M^a(\infty)/d\theta^a]_{TF} = \{\gamma(r-n)Uf'' + (n+\beta)(\alpha+\beta)[\gamma Mf'' - (r-n)(w-Z)/U]\}M/\Delta^a_{TF} > 0, \tag{5.4}$$

hence an increase in global monetary growth raises seignorage revenues (despite a fall in real money balances) and therefore reduces lump-sum taxes. Human wealth increases, because lump-sum taxes fall and because (with a positive birth rate) wage income increases and the real interest rate falls. The increase in human wealth more than off-sets any fall in non-human wealth, so that total wealth and consumption of goods rises. Obviously, joint increases in monetary growth have no effects on net foreign assets.

The increase in the consumption of goods increases global welfare, whilst the increase in inflation and fall in real money balances reduce global welfare, so that the net effect on global welfare is ambiguous.

The above results provide a counter-example to Sidrauski's (1967) result on super-neutrality. These results hold for tax-financed increases in monetary growth, but not for bond-financed increases in monetary growth (even when the birth rate is positive):

$$[dK^a(\infty)/d\theta^a]_{BF} = [dU^a(\infty)/d\theta^a]_{BF} = [dr(\infty)/d\theta^a]_{BF} = 0 \tag{5.5}$$

$$[dM^a(\infty)/d\theta^a]_{BF} = \left(\frac{\xi M}{\Delta^a}\right)\{(r-n)\gamma Uf'' - (n+\beta)(\alpha+\beta)[((r-n)(w-Z)/U) - \gamma f''(D+M)]\} < 0. \tag{5.6}$$

It is not surprising that under bond-finance changes in monetary growth do not affect real outcomes in the long run, because lump-sum taxes and therefore human wealth are unaffected by bond-finance in the long run $(Z = \xi_0 - \xi_1\dot{D} = \xi_0)$. It therefore does not matter that the birth rate drives a wedge between the discount rate used to calculate human wealth and the one used to calculate the government debt, so that real outcomes are unaffected in the long run. The optimal monetary policy is then for each government to implement Friedman's (1969) full liquidity rule, that is drive the nominal interest rates to zero and holdings of real money balances to infinity by setting the monetary growth rates to the difference between the population growth rate and the rate of time preference $(\theta = \theta^* = n - \alpha)$. Obviously, when the tax rule depends on the stock of government debt (say, $Z = \xi_0 + \xi_2 D$), monetary growth affects lump-sum taxation and therefore affects real outcomes in the long run.

When the total birth rate is zero $(n + \beta = 0)$, the effects on real money balances and seignorage revenues are exactly the same as with tax-financed monetary growth. Since seignorage revenues increase, the government can afford to service larger stocks of government debt. There are no effects on total (human plus non-human) wealth. This reflects the Ricardian debt equivalence proposition (e.g., Barro, 1974), because the increase in human wealth arising from the reduction in taxes under the tax-financed increase in monetary growth is exactly the same as the increase in bonds under the bond-financed increase in monetary growth. Hence, for $n + \beta = 0$, one has

$$\left[\frac{dB^a(\infty)}{d\theta^a}\right]_{BF} = \left[\frac{dH^a(\infty)}{d\theta^a}\right]_{TF} = -\left[\frac{dM(\infty)}{d\theta^a}\right]_{BF,TF} = \frac{M}{\alpha+\theta-n} > 0. \quad (5.7)$$

Also, when the birth rate is zero, the long-run effects on social welfare are independent of the residual mode of finance.

Finally, when the birth rate is positive <u>and</u> preferences are non-separable in consumption and real money balances, bond-financed monetary growth can have real effects in the long run (cf., Marini and van der Ploeg, 1987). The reason is that monetary growth affects the nominal interest rate, which in turn affects the proportion spent on consumption of goods. Bond-financed increases in monetary growth decrease (increase) capital and consumption when the elasticity of substitution between goods and real money balances is less (greater) than unity.

5.2 Steady-state effects of a unilateral increase in monetary growth

Again, the case of tax-finance is considered first. The relevant steady-state, tax-financed multipliers for unilateral increases in monetary growth are:

$$[dF(\infty)/d\theta^d]_{TF} = -\tfrac{1}{2}(n+\beta)(\alpha+\beta)\gamma M/\Delta^d_{TF} > 0 \qquad (5.8)$$

$$[dU^d(\infty)/d\theta^d]_{TF} = -(n+\beta)(\alpha+\beta)(r-n)M/\Delta^d_{TF} > 0 \qquad (5.9)$$

$$[dM^d(\infty)/d\theta^d]_{TF} = (n+\beta)(\alpha+\beta)M[((w-Z)/U) - (1-\gamma)]/\Delta^d_{TF} < 0. \qquad (5.10)$$

Use of (4.3) and (4.4) yields

$$[dU(\infty)/d\theta]_{TF} = -\tfrac{1}{2}(n+\beta)(\alpha+\beta)(r-n)M(\Delta^a_{TF} + \Delta^d_{TF})/(\Delta^a_{TF}\Delta^d_{TF}) > 0 \qquad (5.11)$$

and

$$[dU^*(\infty)/d\theta]_{TF} = \tfrac{1}{2}(n+\beta)(\alpha+\beta)(r-n)M\gamma f''[(r+\theta-n)U + (n+\beta)(\alpha+\beta)M]/(\Delta^a_{TF}\Delta^d_{TF}) < 0, \qquad (5.12)$$

so that $[dC(\infty)/d\theta]_{TF} \gtrless 0$ and $[dC^*(\infty)d\theta]_{TF} < 0$. Similarly,

$$[dM(\infty)/d\theta]_{TF} = -\tfrac{1}{2}M\{\gamma Uf'' + (n+\beta)(\alpha+\beta)[1-\gamma-(w-Z)/U](1+\Delta^a_{TF}/\Delta^d_{TF})\}/\Delta^a_{TF}$$
$$(\leq -\tfrac{1}{2}M\gamma Uf''/\Delta^a_{TF} < 0) \qquad (5.13)$$

and

$$[dM^*(\infty)/d\theta]_{TF} = -\tfrac{1}{2}M\{\gamma Uf'' + (n+\beta)(\alpha+\beta)[1-\gamma-(w-Z)/U](1-\Delta^a_{TF}/\Delta^d_{TF})\}/\Delta^a_{TF}$$
$$(\geq -\tfrac{1}{2}M\gamma Uf''/\Delta^a_{TF}) \qquad (5.14)$$

as $\Delta^a_{TF} < \Delta^d_{TF} \leq 0$ (and $w \geq Z + (r+\theta-n)M$ is assumed to hold).

For the case of a zero birth rate, global monetary growth is super-neutral and therefore does not affect average consumption. It follows that the positive effect of home monetary growth on home consumption is exactly off-set by the negative effect on foreign consumption ($[dC(\infty)/d\theta]_{TF} = - [dC^*(\infty)/d\theta]_{TF} > 0$ for $n + \beta = 0$). In general, the birth rate is positive, unilateral monetary growth is non-neutral and therefore the positive effect on home consumption outweighs the negative effect on foreign consumption.

The increase in home monetary growth rate, in general $(n + \beta > 0)$, leads to an equal increase in home inflation $(p = \theta\uparrow)$, a (smaller) increase in the home nominal interest rate $(r + p\uparrow)$ and a fall in the world real interest rate $(r = r^*\downarrow)$. This increases capital accumulation and output, both at home and abroad $(K = K^*\uparrow, \; Y = Y^*\uparrow)$. This is the two-country version of the Mundell-Tobin effect. Foreign inflation is unaffected. This means that each country has an incentive to transfer the burden of reducing the world real interest rate and increasing world activity to the other country, because then it does not need to increase its own monetary growth and inflation rate whilst it does get the increase in activity (cf., van der Ploeg, 1986a).

Since the opportunity cost of holding money balances increases at home and decreases abroad $(r^* + p^*\downarrow)$, it is relatively less attractive to hold money for home agents than it is for foreign agents. There is, therefore, an incentive for home agents to buy bonds from foreign agents $(B\uparrow, B^*\downarrow)$, so that the home (foreign) country accumulates foreign assets (debt) $(F\uparrow)$. The interest payments on net foreign assets allows the home country to run a balance-of-trade deficit, so that home agents can afford to consume more than foreign agents $(C, U\uparrow, C^*, U^*\downarrow)$.

Hence, even though there is a positive spill-over effect of home monetary growth on foreign capital and output, there is a negative spill-over effect on foreign consumption of goods and this decreases foreign social welfare.

The net effect on foreign social welfare depends on what happens to foreign holdings of real money balances. The lower opportunity cost of holding foreign money balances tends to increase it, whilst the lower levels of foreign total consumption and total wealth tend to decrease it, so that the net effect on holdings of foreign money balances is ambiguous ($M^*\downarrow\uparrow$). For small (large) values of the birth rate, foreign money balances decline (increase) and therefore foreign social welfare unambiguously decreases (might increase).

Seignorage revenues at home increase ($\theta M\uparrow$), which allows the home government to cut taxes ($Z\downarrow$). Human wealth of home agents increases, because the wage increases ($w\uparrow$), lump-sum taxes fall and the real interest rate falls. Non-human wealth of home agents can decrease when the fall in home real money balances outweighs the increase in home equity and bond holdings, but any fall must be dominated by the increase in human wealth as total wealth of home agents increases ($A + H\uparrow$). The effect on foreign seignorage revenues is ambiguous ($\theta^* M^*\downarrow\uparrow$), so that the effect on foreign taxes and human wealth is ambiguous. The effect on foreign non-human wealth is also ambiguous, because the fall in foreign bond holdings may or may not be outweighed by the increase in foreign equity and the possible increase in foreign real money balances. However, total foreign wealth decreases ($A^* + H^*\downarrow$).

Now consider the case of bond-finance ($\xi > 0$). A unilateral bond-financed increase in monetary growth has no effect on real activity (see equation (5.5)) and, similarly, it has no effect on net foreign assets in the long run ($[dF(\infty)/d\theta]_{BF} = 0$). The reason is again that long-run taxation is unaffected.

5.3 Dynamic policy simulation

Table 2 shows the impact and steady-state effects of a tax-financed increase of 10 percentage points in monetary growth at home and abroad. Since it is a joint increase, there is no effect on the balance of trade, the current account or the accumulation of foreign assets. In the long run, the real interest rate falls by 0.46 percentage points, so that the capital stock increases by 4.45% and output and the real wage by 0.89%. However, on impact these variables are unaffected. The inflation rate jumps up on impact by 9.54 percentage points and then gradually rises to 10 percentage points. This immediately increases the opportunity cost of holding money balances, so that real money balances and non-human wealth fall on impact by 121.43% and 48.57%, thereby overshooting their steady state by 2.33% and 2.36%, respectively. The increase in seignorage revenues permits a cut in taxation of 36.59%, which gradually rises to 40.56%, and an increase in human wealth of 13.23%, which gradually rises to 15.55%. The overshooting of real money balances can also be seen in the behaviour of total wealth and consumption: on impact they fall by 2.22% and in the long run they increase by 0.11%. Instantaneous welfare also overshoots, since on impact it falls by 26.06% and in the long run by 23.73%.

Table 3 shows the impact and steady-state effects of a tax-financed increase of 10 percentage points in home monetary growth. The effects on the real interest rate, investment, capital stock, output and the wage rate and on the global averages of all other variables are exactly half of what they are under a joint increase in monetary growth. In other words, in the long run there is an interdependent Mundell-Tobin effect, so that a unilateral increase in monetary growth boosts investment and production at home and abroad. At home the increase in seignorage revenues permits a short-run cut in taxation of 27.31%, which increases human wealth by 7.98%. On impact, home real money balances and non-human wealth fall by 126.86% and 50.75%, which ensures that home total wealth and consumption fall by 6.70%. Abroad, the anticipation of higher wage rates, lower taxation, and lower interest rates boosts human wealth on impact by 5.26%. Foreign real money balances and non-human wealth increase by 5.44% and 2.18% on impact. Hence, foreign total wealth and consumption increase by 4.49% on impact. Both at home and abroad, real money balances and total wealth overshoot their equilibrium values, so that total wealth and consumption at home and abroad misadjust in the short run. This causes instantaneous welfare at home to fall by 30.73% on impact and therefore to overshoot by 8.42% and instantaneous welfare abroad to increase by 4.68% on impact and to fall by 1.41% in the long run.

6. Fiscal policy

6.1 Steady-state effects of a joint increase in government spending

Consider the case where taxes are the residual mode of finance first. The steady-state multipliers for a global tax-financed fiscal expansion are:

$$[dK^a(\infty)/dG^a]_{TF} = (n+\beta)(\alpha+\beta)(1-\gamma)(B+K)/(M\Delta^a_{TF}) \leq 0 \tag{6.1}$$

$$[dC^a(\infty)/dG^a]_{TF} = -1 + [(n+\beta)(\alpha+\beta)(1-\gamma)(r-n)(B+K)/(M\Delta^a_{TF})] \leq -1 \tag{6.2}$$

$$[dM^a(\infty)/dG^a]_{TF} = -(1-\gamma)\{Uf'' - (n+\beta)(\alpha+\beta)[1 - Af''/(r+\theta-n)]\}/\Delta^a_{TF} < 0. \tag{6.3}$$

With a zero birth rate $(n + \beta = 0)$, the fall in human wealth, real money balances and therefore private wealth ensures that the joint increase in government spending is completely crowded out by a fall in private consumption of goods. Hence, there is no effect on the real interest rate, capital or output. The fall in human wealth is due to the increase in taxation, which is required to finance the increase in government spending and the fall in seignorage revenues.

With a positive birth rate $(n + \beta > 0)$, real money balances, non-human wealth, human wealth and private consumption of goods fall by a greater amount, so that there is a rise in the real interest rate, crowding out of private investment and a fall in output. Taxes also have to make up for the drop in seignorage revenues, so that they increase by more than the increase in government spending. Human wealth falls for three reasons: wage income falls; lump-sum taxes increase; and the annuity value of after-tax wage income falls due to the rise in the world real interest rate. Social welfare declines, because consumption of both goods and real money balances falls. Obviously, social welfare falls if government spending is of the "hole-in-the-ground" variety $(\gamma' = 0)$. However, if government spending gives utility to private sector agents $(\gamma' > 0)$, social welfare may increase.

Consider now the case where bond issues are the residual mode of government finance. The relevant steady-state multipliers are:

$$[dK^a(\infty)/dG^a]_{BF} = (n+\beta)(\alpha+\beta)(w-\xi_0)(r+\theta-n)/(U\Delta^a) \geq 0 \tag{6.4}$$

$$0 \geq [dC^a(\infty)/dG^a]_{BF} = -1 + [(n+\beta)(\alpha+\beta)(r-n)(1-\gamma)(w-\xi_0)\xi/(M\Delta^a)] \geq -1 \tag{6.5}$$

$$[dM^a(\infty)/dG^a]_{BF} = \{(r-n)(1-\gamma)U + (n+\beta)(\alpha+\beta)[(1-\gamma)((r-n)(r+\theta-n)^{-1}A + D) - \gamma M]\}\xi f''/\Delta \tag{6.6}$$

$$[dD^a(\infty)/dG^a]_{BF} = \{\gamma(r-n)Uf'' + \theta Uf'' + (n+\beta)(\alpha+\beta)[f''[\gamma M + (1-\gamma)D(A-M)/M + (1-\gamma)\theta A/(r+\theta-n)] - (1-\gamma)(w-\xi_0)/M]\}\xi/\Delta^a \quad (< 0). \tag{6.7}$$

When the birth rate is zero $(n + \beta = 0)$, a bond-financed multilateral increase in government spending is completely crowded out by the fall in private consumption and therefore there are no effects on the real interest rate, the capital stock and output. The fall in real money balances is the same as in the tax-financed case, so that the fall in the holdings of bonds in the bond-financed case is exactly the same as the fall in human wealth in the tax-financed case. This is yet again a manifestation of the Ricardian debt equivalence proposition.

Now consider the general situation with a positive birth rate. The main difference with the tax-financed case is that the fall in private consumption leads to less than 100% crowding out of government spending, which implies a fall in the real interest rate and an increase in capital and output. In contrast to the tax-financed case, human wealth rises as the wage increases and the annuity value of wage income increases due to the fall in the interest rate. The effect on real money balances is now ambiguous, because on the one hand total consumption falls and on the other hand the opportunity cost of holding real money balances declines. The government debt must fall in the long run as the increase in government spending means that the government can afford less interest payments. (In the short run the government debt can, of course, increase). In fact, the fall in the real interest rate (when the birth rate is positive) implies that it is easier to service the government debt and therefore bond holdings do not fall as much:

$$0 > [dD^a(\infty)/dG^a]_{\substack{BF \\ \theta=0}} = -(r-n)^{-1} - (n+\beta)(\alpha+\beta)(w-\xi_0)f''D/(U\Delta^a) > -(r-n)^{-1}. \qquad (6.8)$$

6.2 Steady-state effects of a unilateral increase in government spending

Consider the case of tax-finance first. The relevant steady-state multipliers for the global differences are:

$$[dF(\infty)/dG^d]_{TF} = - \tfrac{1}{2}(n+\beta)(\alpha+\beta)(1-\gamma)(K+B)/(M\Delta^d_{TF}) > 0 \quad (6.9)$$

$$[dC^d(\infty)/dG^d]_{TF} = (n+\beta)(\alpha+\beta)\gamma(r+\theta-n)/\Delta^d_{TF} < 0 \quad (6.10)$$

$$[dM^d(\infty)/dG^d]_{TF} = (n+\beta)(\alpha+\beta)(1-\gamma)/\Delta^d_{TF} < 0. \quad (6.11)$$

Use of (4.3) and (4.4) yields:

$$[dC(\infty)/dG]_{TF} = - \tfrac{1}{2} + \tfrac{1}{2}(n+\beta)(\alpha+\beta)[(1-\gamma)(r-n)(B+K)/(M\Delta^a_{TF}) + \gamma(r+\theta-n)/\Delta^d_{TF}] < -\tfrac{1}{2} \quad (6.12)$$

$$[dC^*(\infty)/dG]_{TF} = - \tfrac{1}{2} + \tfrac{1}{2}(n+\beta)(\alpha+\beta)[(1-\gamma)(r-n)(B+K)/(M\Delta^a_{TF}) - \gamma(r+\theta-n)/\Delta^d_{TF}] > [dC(\infty)/dG]_{TF}. \quad (6.13)$$

Consider the case of a zero birth rate $(n + \beta = 0)$ first. A tax-financed increase in home government spending then has no effects on the wage rate, the real interest rate, the capital stock or the level of output, because the increase in home government spending is completely crowded out by the fall in home and foreign consumption $([d(C(\infty) + C^*(\infty))/dG]_{TF} = -1$ for $n + \beta = 0)$. Home consumption falls by more than foreign consumption $([dC(\infty)/dG]_{TF} = - \tfrac{1}{2} - \tfrac{1}{2}\gamma(1-\gamma)^{-1}(r+\theta-n)M(w-Z-\theta M)^{-1} < -\tfrac{1}{2} < [dC^*(\infty)/d\theta]_{TF}$ for $n + \beta = 0)$, which leads to a home balance-of-trade deficit and is associated with an increase in net foreign assets for the home country $([dF(\infty)/dG]_{TF} = \tfrac{1}{2}(K+B)/(w-Z-\theta M) > 0$ for $n + \beta = 0)$. Real money balances at home fall, but abroad they may increase. Foreign non-human and total wealth and home total wealth fall, but home non-human wealth may increase. The incipient excess demand for goods on the world market leads to a rise in the home price level (fall in home real money balances) and, typically, a rise in the foreign price level, which causes home and foreign agents to reduce their demand for goods.

In general, birth rates are positive $(n + \beta > 0)$, so that a tax-financed increase in home government spending increases the world real interest rate and increases capital and output at home and abroad, and is accompanied by more than 100% crowding out by home and foreign consumption. Home consumption falls by more than foreign consumption and the home country accumulates net foreign assets. Real money balances fall on average and they fall more at home than abroad. This implies that welfare at home falls by more than welfare abroad. In fact, foreign consumption, real money balances and welfare may increase.

When bond issues are the residual mode of government finance, the relevant steady-state multipliers are:

$$[dF(\infty)/dG^d)_{BF} = \tfrac{1}{2}(n+\beta)(\alpha+\beta)(r+\theta-n)(w-\xi_0)/(U\Delta^d) = \tfrac{1}{2}(r-n)^{-1} > 0 \qquad (6.14)$$

$$[dU^d(\infty)/dG^d]_{BF} = [dC^d(\infty)/dG^d]_{BF} = [dM^d(\infty)/dG^d]_{BF} = 0 \qquad (6.15)$$

$$[dD^d(\infty)/dG^d]_{BF} = -(r-n)^{-1} < 0. \qquad (6.16)$$

A bond-financed increase in home government spending leads to a fall in the world real interest rate and increases in capital and output, both at home and abroad. This means that there is less than 100% crowding out, that is home plus foreign consumption falls by less than the increase in home government spending. In the long run the home country has a trade deficit of half the increase in government spending, which exactly equals the interest payments on accumulated foreign assets. Hence, in the short run there must have been trade surpluses. In the long run consumption of goods and real money balances are the same in both countries. The increase in home government spending implies that the home government cannot afford to service as much government debt, hence the home country's government debt is lower than the foreign country's government debt by exactly that amount. Note that as far as economic welfare is concerned, the effects on the foreign country are the same as on the home country.

6.3 Dynamic policy simulation

Table 2 presents the impact and steady-state effects of a 10% joint increase in government spending. On impact the wage rate, the real interest rate, capital and output are unaffected. The anticipation of an excess demand for goods leads to rising prices, so that on impact real money balances fall by 3.39% and inflation rises by 0.02 percentage points. The increase in the budget deficit is on impact due to the rise in government spending and fall in seignorage revenues and must be financed by an increase in taxation of 31.15%. The anticipation of lower wages, higher taxes and higher rates of interest reduces human wealth on impact by 3.77%, which, combined with the fall in financial wealth, reduces total wealth and consumption by 3.16% on impact. Since the increase in government spending exceeds the fall in private consumption, investment falls on impact by 0.29%. Social welfare falls on impact by 3.21%. Over time prices continue to rise at a decreasing speed, so that real money balances, seignorage revenues and taxes continue to fall. In the long run, the real interest rate rises by 0.018 percentage points and therefore output and wages fall by -0.04%, whilst capital and investment fall by -0.17%. Hence, in the long run human wealth falls by a further 0.09%. Non-human wealth falls by a further 0.09%, because of the fall in capital and additional falls in real money balances. Hence, total wealth and consumption fall by a further 0.09%. The long-run fall in social welfare also exceeds the short-run fall.

Table 3 presents the impact and steady-state effects of a 10% increase in home government spending. On impact the increase in home government spending leads to a trade deficit of 0.13% of gross output, so that over time the home country accumulates foreign debt. In the long run interest payments on foreign assets fall (despite a small rise in the world real interest rate), which permits a balance-of-trade surplus of 0.05% of gross output. The anticipation of higher prices lowers real money balances on impact at home by 3.18% (undershooting the new equilibrium by 0.27%) and abroad by 0.21% (overshooting by 0.18%). The short-run home public sector deficit is financed by a 30.79% increase in taxation and the foreign deficit (arising from the fall in seignorage revenues) is financed by a 0.36% increase in taxation. This increases human wealth on impact at home by 3.56% and abroad by 0.21%. It follows that total wealth and consumption fall on impact by 2.99% at home and by 0.18% abroad. In the long run home consumption falls by 3.33%, whilst foreign consumption increases by 0.08%. Foreign consumption increases in the long run, because the long run rise in assets of the home country held by foreign agents dominates the falls in foreign equity, real money balances and human wealth. Instantaneous social welfare falls on impact by 3.03% at home and by 0.18% abroad, whilst in the long run it falls by 3.36% at home and increases by 0.10% abroad. Hence, fiscal expansion is a "beggar-thy-neighbour" policy in the short run and a "locomotive" policy in the long run.

7. Tax policy

7.1 Steady-state effects of a joint increase in taxation

The steady-state multipliers for bond-financed multilateral increases in lump-sum taxation are:

$$[dK^a(\infty)/d\xi_0^a]_{BF} = -\ (n+\beta)(\alpha+\beta)\gamma(r+\theta-n)\xi/\Delta^a \leq 0 \qquad (7.1)$$

$$[dC^a(\infty)/d\xi_0^a]_{BF} = -\ (n+\beta)(\alpha+\beta)\gamma(r+\theta-n)(r-n)\xi/\Delta^a \leq 0 \qquad (7.2)$$

$$[dM^a(\infty)/d\xi_0^a]_{BF} = (n+\beta)(\alpha+\beta)[\gamma Mf" - (1-\gamma)(r-n)]\xi/\Delta^a \leq 0 \qquad (7.3)$$

$$[dD^a(\infty)/d\xi_0^a]_{BF} = -\xi\Delta_{TF}^a/\Delta^a > 0. \qquad (7.4)$$

When the birth rate is zero, it is not possible to shift the burden of higher taxation onto future generations and therefore changes in lump-sum taxation have no effects on the real interest rate, capital, output, consumption of goods and of real money balances, and total wealth. The reduction in human wealth resulting from an increase in taxation is exactly off-set by the increase in non-human wealth resulting from an increase in government debt $([dH^a(\infty)/d\xi_0^a]_{BF} = -[dB^a(\infty)/d\xi_0^a]_{BF} = -1/(r-n)$ for $n+\beta = 0)$, which is an illustration of Ricardian debt equivalence.

Now consider the dynamic adjustment. On impact the long-run increase in taxation implies a short-run cut in taxation of $-\xi\xi_0^a$, because government debt and the real interest rate do not jump on impact. The resulting government deficit is financed by borrowing, but this raises taxes. The increase in the interest rate leads to an increase in interest payments on government debt, which means further increases in taxation. The higher taxes in the long run finance the interest payments on the higher government debt.

When the birth rate is positive, a joint increase in taxation increases the world real interest rate and reduces capital and output at home and abroad. This means that consumption of goods and real money balances and total wealth at home and abroad fall. Human wealth falls by more than non-human wealth. It falls for three reasons: (i) taxes have gone up; (ii) wage income has fallen; and (iii) the higher real interest rate has cut the annuity value of after-tax wage income. Increases in lump-sum taxation unambiguously lower welfare.

7.2 Steady-state effects of a unilateral increase in taxation

The steady-state multipliers for the global differences are:

$$[dF(\infty)/d\xi_0^d]_{BF} = -\tfrac{1}{2}(r-n)C/(w-\xi_0) < 0 \quad (7.5)$$

$$[dC^d(\infty)/d\xi_0^d]_{BF} = -C/(w-\xi_0) < 0 \quad (7.6)$$

$$[dM^d(\infty)/d\xi_0^d]_{BF} = -M/(w-\xi_0) < 0 \quad (7.7)$$

$$[dD^d(\infty)/d\xi_0^d]_{BF} = -\xi\Delta_{TF}^d/\Delta^d > 0. \quad (7.8)$$

Application of (4.3) and (4.4) yields $[dC(\infty)/d\xi_0]_{BF} < 0$, $[dM(\infty)/d\xi_0]_{BF} < 0$, $[dD(\infty)/d\xi_0]_{BF} > 0$,

$$[dC^*(\infty)/d\xi_0]_{BF} = -[(r-n)U + (n+\beta)(\alpha+\beta)(D+M)]\gamma f''(r+\theta-n)C\xi/[2\Delta^a(w-\xi_0)] > 0 \quad (7.9)$$

$$[dM^*(\infty)/d\xi_0]_{BF} = -\{(r+\theta-n)(r-n)U + (n+\beta)(\alpha+\beta)[(r+\theta-n)(D+M) - (w-\xi_0]\}.$$

$$\gamma Mf''\xi/[2\Delta^a(w-\xi_0)] \quad (>0) \quad (7.10)$$

and (ignoring second-order terms in $(n+\beta)(\alpha+\beta)$)

$$[dD^*(\infty)/d\xi_0]_{BF} = -\tfrac{1}{2}\xi^2(n+\beta)(\alpha+\beta)(1-\gamma)Cf''(r-n)(r+\theta-n)\theta/(\Delta^a\Delta^d) \quad (7.11)$$

(which is positive for $\theta > 0$ and is negative for $\theta < 0$).

Hence, an unanticipated, permanent, bond-financed increase in home taxation leads in the long run to a fall in home consumption of goods, a fall in home holdings of real money balances, an increase in home government debt, a fall in net foreign assets of the home country, a trade surplus, a rise in the world real interest rate, and falls in investment, capital and output. Foreign human wealth falls, because wages fall and the real interest rate rises. Obviously, home human wealth falls even further due to the increase in home taxation. Foreign consumption of goods and real money balances increases, so that home welfare falls and foreign welfare increases.

8. Imperfect substitution between home and foreign goods

So far, the two-country model discussed in this paper incorporated the "law of one price". Here the unrealistic assumption of purchasing power parity is replaced by the assumption of imperfect substitution between home and foreign goods. It is also assumed that each country is completely specialised in production. Real variables (except F) are now deflated by the ideal cost-of-living index (CPI), say P_c, rather than by the home price level, P. This means that the analysis of Sections 2.1-2.4 is as before, except that $p(t) \equiv \dot{P}(t)/P(t)$ in equations (2.2), (2.4), (2.19) and (2.14) is replaced by $p_c(t) \equiv \dot{P}_c(t)/P_c(t)$. The main changes occur in Section 2.5

The first stage of the consumer's decision problem is to decide on its total consumption and savings and therefore has an intertemporal nature (see Section 2.1). The second stage is concerned with how much to consume of home goods, C_D, and of foreign goods, C_M. With Cobb-Douglas preferences, consumers choose C_D and C_M to maximise the utility function $(C_D/\omega)^{\omega}(C_M/(1-\omega))^{1-\omega}$ subject to the static budget constraint $PC_D + P^*EC_M = P_CC$ where E denotes the nominal exchange rate. This yields $C_D = \omega P_CC/P$ and $C_M = (1-\omega)P_CC/(\nu P)$ where the real exchange rate is defined as $\nu \equiv P^*E/P$. Upon substitution into the utility function, one obtains the CPI as $P_C = P^{\omega}(P^*E)^{1-\omega}$ so that $C_D = \omega\nu^{1-\omega}C$ and $C_M = (1-\omega)\nu^{-\omega}C$. To keep matters simple, it is assumed that governments have the same preferences over home and foreign goods as the private sector so real government spending on home goods is given by $G_D = \omega\nu^{1-\omega}G$ and on foreign goods is given by $G_M = (1-\omega)\nu^{-\omega}G$. Equation (2.16) is replaced by the condition for equilibrium in the home goods market,

$$Y = C_D + G_D + I + C_M^* + G_M^*$$

$$= (P_C/P)(C+G) + I + [C_M^* + G_M^* - \nu(C_M+G_M)], \quad (8.1)$$

and the condition for equilibrium in the foreign goods market,

$$Y^* = C^*_D + G^*_D + I^* + C_M + G_M$$

$$= (P^*_C/P^*)(C^*+G^*) + I^* + [C_M + G_M - (C^*_M+G^*_M)/\nu], \qquad (8.2)$$

where the terms in square brackets denote the balances of trade. Similarly, equation (2.17) describing the current-account dynamics is replaced by

$$\dot{F} = (r-n)F + Y - (P_C/P)(C+G) - I$$

$$= (r-n)F + [C^*_M + G^*_M - \nu(C_M+G_M)] \qquad (8.3)$$

where $F \equiv (B-D)P_C/P$ and $F^* = - F/\nu$. Real non-human wealth of home agents is given by $A = K + M + D + \nu^{-(1-\omega)}F$ and of foreign agents is given by $A^* = K^* + M^* + D^* - \nu^{-\omega}F$. The condition for uncovered interest parity becomes $r + p_c = r^* + p^*_c + e^e$ or $r = r^* + (2\omega-1)\dot{\nu}^e/\nu$.

The complete two-country model with imperfect substitution between home and foreign goods is particularly simple when the share of imported goods is fifty percent ($\omega=\frac{1}{2}$), because then $r = r^*$ and therefore $K = K^*$, $Y = Y^*$ and $w = w^*$. Subtraction of (8.1) and (8.2) then yields $\nu = 1$, so that $P_C = P = P^*E$. In other words, the special case $\omega = \frac{1}{2}$ corresponds to the purchasing power parity model discussed in Sections 2-7. The general case of $\omega > \frac{1}{2}$ can be summarised by ten ordinary differential equations in terms of K, K^*, F, ν, U, U^*, M, M^*, D and D^*, where the first three variables are assumed to be predetermined and the remainder are assumed to be non-predetermined.[1] Alternatively, one obtains a sub-system for the global averages, $(K^a, U^a, M^a, D^a)'$, and an independent sub-system for the global differences, $(K^d, F, \nu, U^d, M^d, D^d)'$. Table 1 shows that the eigenvalues

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[1] This assumes that initially no gross foreign assets are held, so that jumps in the real exchange rate do not lead to jumps in F.

associated with the global averages for the tax-financed case are the same as under purchasing power parity. This is not so for the global differences; there are now two stable eigenvalues associated with K^d and F and three eigenvalues associated with ν, U^d and M^d. The global differences now adjust even more slowly, that is they take about 375 rather than 253 time units to settle down within 0.1% of the steady state.

The effects of joint changes in economic policy are the same irrespective of whether purchasing power parity holds or home and foreign goods are imperfect substitutes. Table 3 compares the effects of tax-financed increases in monetary growth under imperfect substitution between home and foreign goods and under purchasing power parity. The main point to notice is that in the first case the real exchange rate, ν, overshoots its equilibrium value. For a monetary expansion it depreciates by 5.35% on impact and appreciates by 3.17% in the long run. For a fiscal expansion it appreciates by 0.21% on impact and depreciates by 0.12% in the long run. Also, investment now responds more at home and less abroad in the short run.

9. Concluding remarks

A two-country, optimising model with capital accumulation, floating exchange rates, uncovered interest parity, perfect foresight, finite lives and population growth has been formulated. For the special case of a zero birth rate, the discount rate used to calculate human wealth is the same as the discount rate used to calculate non-human wealth and government debt. It follows that for this case individuals are indifferent between tax-finance and bond-finance or money-finance, so that Ricardian debt-neutrality and super-neutrality hold. Note that these neutralities occur in economies where the probability of death equals the rate of population decline. Sufficient conditions for these neutralities are infinite lifetimes and no population growth. The general case of non-zero birth rates is best analysed by decomposing the system into global averages and global differences. A tax-financed increase in monetary growth leads to an interdependent Mundell-Tobin effect, that is the world real interest rate falls whilst capital accumulation and output increase. A home monetary expansion leads to an increase in home consumption, a fall in foreign consumption, a home balance-of-trade deficit, and an increase in home holdings of net foreign assets. If the monetary expansion occurs through open-market operations, money is super-neutral. A tax-financed fiscal expansion leads to a rise in the real interest rate, crowding out of private investment, a fall in output, and falls in real money balances, non-human wealth and human wealth. There is more than 100% crowding out of private consumption of goods. Taxes increase by more than government spending, because they have to make up for the loss in seignorage revenues. When government spending is financed by bond issues, there is less than 100% crowding out, human wealth increases, the real interest rate falls, capital accumulation increases and the government debt rises. A home fiscal expansion leads to a bigger fall in home consumption than in foreign consumption, so that the home country accumulates net foreign assets and experiences a trade deficit. A bond-financed increase in lump-sum taxation leads to an increase in the world real interest rate, a fall in capital and output, a fall in consumption of goods and real money balances, a fall in human and non-human wealth, an increase in government debt, and a fall in welfare. A home increase in taxation leads to a trade surplus, a fall in net holdings of foreign assets, a fall in home welfare and an increase in foreign welfare.

An interesting area for further research is the optimal determination of fiscal policy (see Calvo and Obstfeld, 1987) and of monetary policy. This raises the issue of how the welfare of different generations should be weighed in order to construct a social welfare function. The problem of time inconsistency arises because Central Banks have an incentive to levy a surprise inflation tax. Obviously, the problem of optimal economic policy needs to be considered in an interdependent world and therefore issues of international policy coordination emerge. Most studies on international policy coordination have focussed on monetary disinflation in two-country, real-exchange-rate overshooting models (e.g., Miller and Salmon, 1985; Currie and Levine, 1985; Oudiz and Sachs, 1985; Rogoff, 1985). However, such models imply ad-hoc welfare functions and therefore do not permit a proper game-theoretic analysis of time consistency and the merits of international policy coordination. In two-country optimising models of optimal taxation, one finds that in the absence of international cooperation government spending is excessive (Kehoe, 1986, 1987; van der Ploeg, 1987a,b). Furthermore, international policy coordination can aggravate the problems of credibility and time inconsistency so that cooperation between governments in the absence of pre-commitment vis-à-vis the private sector can be counter-productive (Rogoff, 1985; Kehoe, 1986; van der Ploeg, 1987b). Obviously, it is interesting to investigate the scope for international policy coordination in the particular two-country model developed in this paper. An ad-hoc analysis shows that, in the absence of international policy coordination, monetary growth is too low, real interest rates are too high and capital and output are too low (van der Ploeg, 1986). However, the paper shows that an increase in home monetary growth may well be a beggar-thy-neighbour policy as foreign consumption falls and therefore there may well be an inflationary bias in monetary growth.

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Table 1: Numerical specification

PARAMETER VALUES

$\alpha = \beta = n = 0.02$; $\delta = 0.1$; $\bar{f}(K,1) = 0.65K^{0.2}$; $\gamma = 0.08$; $\omega = 0.75$;

$\xi = 0.0$ for tax-finance and $\xi = 1.0$ for bond-finance; $\xi_0 = 0.05125$;

$G = G^* = 0.13$; $\theta = \theta^* = 0.07$

STEADY STATE (symmetric)

$w = 0.52$; $r = 0.03$; $p = 0.05$; $r + p = 0.08$;

$C = 0.4$; $I = 0.12$; $Y = 0.65$; $f(K) = 0.55$; $V = K = 1.0$;

$H = 9.375$; $A = 3.125$; $M = 1.25$; $D = B = 0.875$; $F = 0$;

$\theta M = 0.0875$; $G - \theta M = 0.0425$; $Z = 0.05125$;

$U = 0.5$; $\gamma \log(C) + (1-\gamma)\log(M) = -0.6884$.

EIGENVALUES: TAX-FINANCE AND PURCHASING POWER PARITY

-0.1991, 0.0838 and 0.2153 for the global averages;

-0.0273, 0.0418 and 0.0855 for the global differences.

EIGENVALUES: TAX-FINANCE AND IMPERFECT SUBSTITUTION

-0.1991, 0.0838 and 0.2153 for the global averages;

-0.3170, -0.0184, 0.0324, 0.0848 and 0.2153 for the global differences.

Table 2: Effects of joint, unanticipated, tax-financed changes in economic policy

	10% increase in monetary growth		10% increase in government spending	
Percentage changes in	Impact	Final	Impact	Final
U = U*, C = C*	-2.217	0.111	-3.164	-3.254
I = I*	7.390	4.454	-0.288	-0.174
Y = Y*, w = w*	0.0	0.891	0.0	-0.035
K = K*	0.0	4.454	0.0	-0.174
M = M*	-121.425	-119.098	-3.389	-3.480
A = A*	-48.570	-46.214	-1.356	-1.448
H = H*	13.234	15.553	-3.766	-3.857
Z = Z*	-36.591	-40.564	31.153	31.308
r = r* 1)	0.0	-0.463	0.0	0.018
p = p* 1)	9.537	10.0	0.018	0.0
Welfare 2)	-26.059	-3.209	-3.209	-3.300

1) For this variable, the arithmetic change in percentage points is given.

2) Instantaneous welfare is defined as $c^{\gamma} m^{1-\gamma} g^{\gamma'}$. The calculations assume that government spending is of the "hole-in-the-ground" variety ($\gamma' = 0$). If it is not, then government spending can increase welfare (e.g., the final effect is 4.7% rather than -3.3% for $\gamma' = 0.8$).

Table 3: Effects of unanticipated, tax-financed changes in home economic policy

Percentage changes in	10% increase in monetary growth				10% increase in government spending			
	Purchasing power parity		Imperfect substitution		Purchasing power parity		Imperfect substitution	
	Impact	Final	Impact	Final	Impact	Final	Impact	Final
U,C	-6.703	2.105	-7.022	3.207	-2.989	-3.332	-2.976	-3.375
U*, C*	4.486	-1.994	4.805	-3.096	-0.175	0.078	-0.187	0.121
C_D	-	-	-5.684	2.414	-	-	-3.028	-3.344
C^*_D	-	-	3.467	-2.303	-	-	-0.135	0.090
C_M	-	-	-11.034	5.585	-	-	-2.820	-3.468
C^*_M	-	-	8.817	-5.474	-	-	-0.344	0.213
ν	0.0	0.0	5.350	-3.171	0.0	0.0	-0.209	0.124
b [1), 2)]	3.443	-1.262	2.365	-1.293	-0.134	0.050	-0.092	0.050
I	3.695	2.227	4.690	2.227	-0.144	-0.087	-0.183	-0.087
I*	3.695	2.227	2.700	2.227	-0.144	-0.087	-0.105	-0.087
Y=Y*, w=w*	0.0	0.445	0.0	0.445	0.0	-0.017	0.0	-0.017
K=K*	0.0	2.227	0.0	2.227	0.0	-0.087	0.0	-0.087
M	-126.862	-120.000	-127.034	-118.898	-3.177	-3.445	-3.171	-3.488
M*	5.437	0.902	5.608	-0.200	-0.212	-0.035	-0.219	0.008
F/A [1)]	0.0	26.880	0.0	26.240	0.0	-1.024	0.0	-1.050
A	-50.745	-21.058	-50.813	-19.956	-1.271	-2.429	-1.268	-2.472
A*	2.175	-25.156	2.243	-26.258	-0.085	0.981	-0.088	1.024
H	7.978	9.826	7.575	10.928	-3.561	-3.633	-3.545	-3.676
H*	5.256	5.727	5.659	4.625	-0.205	-0.223	-0.221	-0.180
Z	-27.309	-39.025	-27.016	-40.906	30.791	31.248	30.779	31.321
Z*	-9.282	-1.540	-9.575	0.342	0.362	0.060	0.373	-0.013
r=r* [1)]	0.0	-0.232	0.0	-0.232	0.0	0.009	0.0	0.009
p [1)]	9.613	10.0	9.601	10.0	0.015	0.0	0.016	0.0
p* [1)]	-0.076	0.0	-0.064	0.0	0.003	0.0	0.003	0.0
Welfare [3)]	-30.734	-22.316	-31.024	-21.214	-3.026	-3.355	-3.015	-3.398
Welfare* [3)]	4.676	-1.414	4.966	-2.517	-0.182	0.098	-0.194	0.055

1) For this variable, the arithmetic change in percentage points is given.

2) This variable is the ratio of the balance of trade to gross output, that is $(Y - C - I - G)/Y$ for the case of purchasing power parity and $[C^*_M + G^*_M - \nu(C_M + G_M)]/Y$ for the case of imperfect substitution between home and foreign goods.

3) Welfare is defined as $c^{\gamma}m^{1-\gamma}$.

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