European Economic Review 34 (1991) 1–22. North-Holland

The non-neutrality of inflation for international capital movements

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Received July 1989, final version received November 1989

This paper studies the question of how unilateral changes in the rate of inflation affect the international allocation of capital. Presenting a model that incorporates a transaction motive for money holding and capital income taxation with historical cost accounting, it counters the view that inflation will be neutral in a world of perfect foresight and costless arbitrage: under mild conditions, domestic inflation will unambiguously induce a capital export. The paper includes a discussion of the Fisher effect. The empirical observation of a less than one-to-one translation of inflation into nominal intererest rates is shown to be compatible with the model, and in fact the capital export turns out to be stronger the lower the degree of translation.

1. The problem

The very high degree of integration in today's world capital markets means that monetary and fiscal policies can generate huge international capital flows. This has been very clearly demonstrated by the recent experience of the United States, now the world's biggest debtor country. This paper analyzes the effect of differences in national inflation rates on the direction of such capital flows, or, more precisely, it looks at what happens to the allocation of a given stock of capital between two countries when one country's inflation rate rises. In the absence of closely coordinated monetary policies and in a world of floating exchange rates, this is a non-trivial theoretical problem which is of immediate practical concern.

Two major reasons for a general non-neutrality of inflation are frictions created by reduced money holding and an increase in the real burden of capital income taxation due to historical cost accounting. Previously, much work has been done to clarify the closed-economy implications of these effects.[1] Their international implications, however, do not seem to be so

*The author gratefully acknowledges useful comments by Peter Howitt and Slobodan Djajic. This paper is part of the NBER research project on International Aspects of Taxation.

[1]Cf. Auerbach (1983) and Howitt (1986) for overviews of the literature. The present paper is an extension of previous work in German [Sinn (1987b)] where the effects of inflation and historical cost accounting on international capital movements and economic growth were studied, but no motive for money holding was included. For a related study of the effect of historical cost accounting on government revenue from inflation see Sinn (1983).

well known and, up to now, they have not been analyzed theoretically. The motivation for the present research is to provide such a theoretical analysis.

The paper presents a simple two-country model with perfect capital mobility, imperfectly integrated, non-indexed capital income tax systems, and pecuniary transactions costs, the latter being the motive for money holding. A distinction is made between bonds, corporate shares, and real capital, and much emphasis is placed on the relationships between the domestic and international capital market equilibria. The paper is based on an explicit model of a corporate firm.

There are two equally popular opposing views on the significance of inflation for international capital flows, apart from the view that inflation is neutral. One is that real investment and capital import are stimulated by an increase in inflation, because the nominal interest rate does not adjust sufficiently. The other is that capital prefers monetary stability and moves into countries that are successful in keeping their price levels constant (Switzerland).

The research presented here lends support to the second view. It is argued that, with any given stock of real domestic capital, inflation reduces the marginal product of capital net of transactions costs and, in addition, increases the tax wedge between the latter and the real net rate of interest of the firm. Assuming that capital gains on corporate shares and on foreign currency are taxed at the same rate, it is then shown that the decline in this interest rate results in an increase in foreign portfolio investment and a corresponding outflow of real capital.

These findings are not compatible with previous studies on the effect of inflation on international capital movements. Section 4 discusses the related literature and attributes the differences to the neglect of an explicit motive for money holding, the assumption of indexed tax systems, and asymmetries in the taxation of capital gains from share and currency appreciation.

The paper includes an analysis of Fisher's problem of the extent to which inflation drives up the nominal interest rate. Empirical investigations have shown that, even in the long run, inflation rate changes do not translate into changes in nominal interest rates on a one-to-one basis. It is demonstrated that this observation is perfectly compatible with the present model and can, in fact, be predicted if the economy has sufficiently short-lived real assets or sufficiently low tax rates and is large in the sense that capital movements have little effect on its marginal product of capital. Thus, not only the view that inflation induces capital imports, but also the view that an insufficient adjustment of interest rates with necessity implies an increase in real investment is rejected by the model. If the adjustment is less than the Fisher effect predicts, then this may be an indication that the transactions costs and historical cost accounting effects are particularly strong, producing both a sharp decline in domestic investment and a large increase in capital exports.

2. Microeconomic foundations and domestic equilibrium

The analysis starts with the decision problem of a representative domestic firm under the influence of inflation and taxation. Without loss of generality, the firm is assumed to be a corporation. The firm's behavior is derived assuming an equilibrium in the domestic asset market which requires asset holders to be indifferent between holding corporate shares and bonds. The model is specified in continuous time and all agents correctly anticipate the time paths of all market prices.

Retained and distributed profits are taxed at the rate τ_f, and there is an additional tax rate τ_d on distributed profits to mimic alternative degrees of integration between corporate and personal taxation. Asset holders' accrued capital gains from corporate shares are taxed at the rate τ_c and their interest income is taxed at the rate τ_a. To abbreviate notation, *tax factors* are frequently used in this paper that are defined as one minus the corresponding *tax rates*: $\theta_j \equiv 1-\tau_j$, $j=a, c, d, f$, with $0<\theta_j \leqq 1$.

Let i denote the (gross) nominal market rate of interest and π the inflation rate. Then the firms' (f) and the asset holders' (a) real net rates of interest are given by

$$r_j \equiv i\theta_j - \pi, \qquad j=f, a. \tag{1}$$

There are two stocks of capital defined in real terms: the actual stock K and the accounting stock A. Let I denote real gross investment, δ the true economic depreciation rate, γ the depreciation rate applied for tax purposes, and π the inflation rate. Then

$$\dot{K} = I - \delta K,$$

and

$$\dot{A} = I - [\gamma + \pi(1-\alpha)]A. \tag{3}$$

where α (with $\alpha=0$ or $\alpha=1$) is the tax-exempt proportion of inflation-induced accounting profit. Historical cost accounting, the rule among OECD countries,[2] is characterized by $\alpha=0$ and full indexation of depreciation allowances is characterized by $\alpha=1$. While the paper concentrates on the case $\alpha=0$, it includes the case $\alpha=1$ for interpretative purposes, for example to confront its results with those of Hartman (1979) in section 4.

A central variable in the decision problem of the firm is the dividends it

[2]An exception to this rule is Denmark, where indexation of depreciation allowances was introduced in 1982.

pays to its shareholders. After imposition of the profit tax rate (τ_f), but before imposition of the dividend tax rate (τ_d), real dividends are given by[3]

$$D=\theta_f\{F(K,L)-T[F(K,L),M]-\delta K-wL\}$$
$$-r_f B-\pi M+\tau_f(\gamma A-\delta K)+\dot{B}+Q-\dot{K}-\dot{M}. \tag{4}$$

Here $F(K,L)$ is a well-behaved production function $[F_j>0,\ F_{jj}<0,\ j=K,L;\ F_K(0,L)=F_L(K,0)=\infty,\ F_K(\infty,L)=F_L(K,\infty)=0]$ with capital and labor as inputs, and $T(F,M)$ is a function that relates the real transactions cost T to the firm's real transactions volume F and its real stock of money balances M. For simplicity, K, F, and T are all stated in units of a homogeneous good. In the spirit of the Baumol–Tobin theory, it is assumed that $T_F>0$, $T_M<0$, T_{FF}, $T_{MM}>0$, $T_{FM}(=T_{MF})<0$, $T_M(F,0)=-\infty$, $T_M(F,\infty)=0$, and $T_{MM}T_{FF}>T_{FM}^2$ (convexity).[4] $B\gtreqless 0$ is the firm's real stock of debt, $w>0$ the real wage rate, and $Q\geqq 0$ the real revenue from selling new shares.

In accordance with Fisher's separation theorem,[5] the firm has the goal of maximizing the real market value V of its equity given the initial values of its state variables, K, A, M, and B. To analyze the implications of this goal, it is crucial to derive first the market value function itself. This can best be done by reference to the following arbitrage condition in nominal terms that requires asset holders to be indifferent between holding corporate shares and bonds and that must hold in a domestic capital market equilibrum at all points in time

$$VPi\theta_a=DP\theta_d+(\dot{v}P+\dot{P}v)n\theta_c+(\dot{n}vP-QP)\theta_c \quad \text{(domestic equilibrium)} \tag{5}$$

Here, P is the price level, v is the real value per share and n the number of outstanding shares The left-hand side of eq. (5) measures the nominal post-tax interest return the asset holders could enjoy if they sold their shares. The right-hand side measures the return from continuing to hold shares. The first term, $DP\theta_d$, is dividends net of all taxes. The second, $(\dot{v}P+\dot{P}v)n\theta_c$, indicates real and inflation-induced capital gains from existing shares net of the capital gains tax. The third expression on the right-hand side of (5) is the net-of-

[3]The corresponding equation in nominal terms is $D^*=P(F-T)-I^*-\dot{M}^*-iB^*-w^*L+Q^*+\dot{B}^*-\tau_f[P(F-T)-\gamma A^*-iB^*-w^*L]$ where an asterisk indicates a nominal value and P is the price level. Using (1) and $\dot{P}/P=\pi$ it is straightforward to transform this equation into (4).

[4]To avoid the problem of increasing returns to scale in the transactions technology and to ensure the existence of a competitive equilibrium it is not assumed that $T_{FF}=0$ as in the Baumol–Tobin theory. Instead, it is assumed with $T_{FF}>0$ that the 'cost per trip to the bank' is a rising function of the number of 'trips'. (Alternatively, it could be assumed that $T_{FF}=0$ while the degree of homogeneity of $F(K,L)$ is sufficiently far below unity.)

[5]There are kinds of transactions costs that would render the separation therorem invalid. However, the firm-internal costs assumed here clearly do not create problems.

capital-gains-tax value of the current flow of purchasing options issued to existing shareholders. In the special case of countries that do not have such options, $\dot{n}vP - QP = 0$ can be assumed since shares cannot be sold above their market price and existing shareholders will object to a policy of diluting their assets. In general, however, the flow of purchasing options should be allowed to contribute to the return from shareholding: $\dot{n}vP - QP \geqq 0$.

Noting that $\pi = \dot{P}/P$ and $\dot{V} = \dot{n}v + \dot{v}n$, (5) can easily be transformed into the differential equation

$$\dot{V} = -(\theta_d/\theta_c)D + Q + V[i(\theta_a/\theta_c) - \pi]. \tag{6}$$

Assuming that $V(t) = 0$ if, from time t onwards, the firm never issues new shares and never pays out any dividends, the equation

$$V(t) = \int_t^\infty \left[\frac{\theta_d}{\theta_c} D(u) - Q(u)\right] \exp\left[-\int_t^u i(x)\frac{\theta_a}{\theta_c} - \pi(x)\,\mathrm{d}x\right] \mathrm{d}u \tag{7}$$

can be derived by integrating (6). It is assumed here that D; Q, i, and π are piecewise continuous functions of time t, shaped in a way that ensures the existence of (7).

The firm's control variables can be taken to be its real net investment $\dot{K}$, its net increase in real debt $\dot{B}$, its net increase in real money balances $\dot{M}$, the shareholders' real injections Q, and the employment of labor L_0. Its goal is therefore

$$\max_{\{\dot{K}, \dot{B}, \dot{M}, Q, L\}} V(0).$$

The constraints of this optimization problem are the historically given initial conditions $K(0) = K_0 > 0$, $B(0) = B_0 \gtreqless 0$, $A(0) = A_0 > 0$, and $M(0) = M_0 > 0$; non-negativity constraints for new share issues, the two stocks of capital (actual and accounting), money balances, and employment of labor ($Q, K, A, M, L \geqq 0$); as well as the equation of motion (3) for the real accounting value of the firm's capital stock. The current-value Lagrangean for this optimization problem is

$$\mathscr{L} = \frac{\theta_d}{\theta_c} D - Q + \lambda_K \dot{K} + \lambda_A \dot{A} + \lambda_B \dot{B} + \lambda_M \dot{M} + \mu_Q Q. \tag{8}$$

Here, λ_K, λ_A, λ_B, and λ_M are shadow prices of the four state variables K, A, B, and M, and μ_Q is a Kuhn–Tucker multiplier for the non-negativity constraint on new share issues. The constraints on K, A, M, and L are assumed not to be binding. Recall that dividends are defined by (4).

An obvious necessary optimization condition of this problem is that the marginal product of labor net of transactions costs equal the wage rate: $F_L(1-T_F)=w$. A more interesting condition that follows from $\partial\mathscr{L}/\partial\dot{B}=0$ and the canonical equation for B, $\dot{\lambda}_B-[(i\theta_a/\theta_c)-\pi]\lambda_B=-\partial\mathscr{L}/\partial B$, is

$$r_f=i\frac{\theta_a}{\theta_c}-\pi \tag{9}$$

which, because of (1), implies that

$$\theta_f\theta_c=\theta_a. \tag{10}$$

This condition ensures that debt and retentions are equivalent sources of finance and, in the absence of financial constraints with regard to debt financing, it is also necessary for existence. If (10) is not satisfied, there is a loophole in the tax system which offers firms a profitable arbitrage opportunity, rendering the optimization problem insoluble. To avoid the difficulty of formulating appropriate financial constraints in the presence of inflation, it is assumed in this paper that the tax system satisfies (10).

While (10) is introduced primarily for simplification, it should be mentioned that this condition is consistent with the kind of financial and tax adjustment mechanism described by Miller (1977). When the asset holders' interest income is subject to progressive rates of taxation, any violation of condition (10) would induce changes in the firm's financial decisions up to the point where a sufficiently large change in the representative shareholder's tax base occurs to reinstate this condition. The constellation $\theta_f\theta_c>\theta_a$, for example, would imply that the firm has an incentive to retain all profits. The representative shareholder's personal tax base would therefore decline and so, too, would the marginal personal tax rate τ_a. This raises θ_a until (10) is satisfied. Although this mechanism has not been explicitly modeled above, (9) and (10) can be interpreted as an attempt to depict a *Miller equilibrium*.[6] Admittedly, the tax system's flexibility may not be large enough to produce the Miller equilibrium exactly. Even in this case, however, the assumption of equal marginal tax rates on retained profits and personal interest income seems a natural idealization that offers useful insight into the allocative effects of inflation without burdening the model with excessive formal complications. Note that the assumed tax system remains more general than, for example, a Schanz–Haig–Simons system, where the overall tax rate on

[6]Cf. the alternative descriptions of the Miller equilibrium that are given in Auerbach (1983) and Sinn (1987a, chapter 4.3.4.).

distributed profits would also have to be brought into line with the others ($\theta_d\theta_a=\theta_f\theta_c=\theta_a$; i.e., $\theta_d=1$).

Eq. (10) implies that the equivalence between retained profits and debt is independent of the dividend tax rate τ_d. However, this neutrality property of dividend taxation does not carry over to the choice of new share issues as a marginal source of equity finance.[7] As can be seen from $\partial\mathscr{L}/\partial Q=(\theta_d/\theta_c)-1+\mu_Q=0$, $\mu_Q Q=0$, it holds that $Q=0$ if $\tau_d>\tau_c$ and $Q\geqq 0$ if $\tau_d=\tau_c$. Given (10), the latter case refers to a full-imputation system as in Germany or Italy where $\theta_f\theta_d=\theta_a$ since dividends are subjected to the same overall tax burden as shareholder interest income. The former case, $\tau_d>\tau_c$, characterizes classical or partial-imputation tax systems with a correspondingly higher overall tax burden on dividends; such tax systems exist in most countries. The question of which of these systems prevails can be left open, but, in order to ensure existence, it is assumed that $\theta_f\theta_d\leqq\theta_a$. With the possible exception of Norway, this condition is satisfied in all OECD countries.

The most important aspects of the firm's decisions are its money holding and its real investment. The appendix derives the corresponding marginal conditions. One, following from $\partial\mathscr{L}/\partial\dot{M}=0$ and $\dot{\lambda}_M-\lambda_M[(i\theta_a/\theta_c)-\pi]=-\partial\mathscr{L}/\partial M$, is

$$i=-T_M. \tag{11}$$

It says that the marginal saving of real transactions costs through money holding equals the nominal rate of interest. This is a standard result of monetary theory. Note that the tax system does not interfere with (11) as the firm's transactions costs are tax-deductable.

The other condition, following from $\partial\mathscr{L}/\partial\dot{K}=0$ and $\dot{\lambda}_K-\lambda_K[(i\theta_a/\theta_c)-\pi]=-\partial\mathscr{L}/\partial K$, is[8]

$$r_f=\theta_f[F_K(1-T_F)-\delta]+(\gamma-\delta)(\tau_f-\lambda)-\lambda\pi(1-\alpha). \tag{12}$$

The variable λ is defined as $\lambda\equiv\lambda_A\theta_c/\theta_d$ and measures the firm's internal present value of depreciation allowances per unit of accounting capital. Assuming that r_f and π are time-invariant equilibrium values, it is shown in the appendix that

[7]This is due to the trapped equity argument embodied in the present model. For an overview of the literature see Sinn (1987a, chapter 5.3.6).

[8]In the special case $T_F=\gamma-\delta=\alpha=0$, this equation reduces to a formula derived by Alan Auerbach in the appendix of a paper by Feldstein, Green, and Sheshinski (1978). If, in addition, it is assumed that all assets are short-lived ($\delta\to\infty$), then (12) reduces to $F_K-\delta=i-\pi$, an equation derived by King (1977, p. 244). Note that the model is specified in continuous time. The case $\delta\to\infty$ therefore implies the annual depreciation rate in a discrete time model to be 100%.

$$\lambda = \frac{\tau_f \gamma}{r_f + \gamma + \pi(1-\alpha)} \tag{13}$$

which obviously implies that

$$0 \leqq \lambda < \tau_f, \ \lambda \begin{Bmatrix} =0 \\ \to \tau_f \end{Bmatrix} \ \text{if} \ \gamma \begin{Bmatrix} =0; & \text{no tax depreciation} \\ \to \infty; & \text{immediate write-off} \end{Bmatrix}. \tag{14}$$

Eq. (12) shows that the tax system drives a wedge between the marginal product of capital net of transactions costs and depreciation, $F_K(1-T_F)-\delta$, and the firm's real net rate of interest, r_f. Without inflation ($\pi=0$) and with true economic depreciation ($\gamma=\delta$), this wedge is determined by the corporate tax rate (τ_f) alone. With inflation ($\pi>0$), historical cost accounting ($\alpha=0$), and a percentage depreciation rate that would be correct in the absence of inflation ($\gamma=\delta$), the wedge becomes bigger. A possibility for compensating for this effect would be to index depreciation allowances ($\alpha=1$), but governments typically prefer accelerated depreciation allowances instead ($\gamma>\delta$). Since (14) shows that $\tau_f-\lambda>0$, this would counteract the term $\lambda\pi$ in (12) and would therefore indeed be a favorable measure. The task of the following section is to analyze the pure effects of inflation in the presence of historical cost accounting when the government does not adjust the tax depreciation rate to compensate for a change in the inflation rate. For this reason it will henceforth be assumed that $\delta=\gamma$.

It is important to note that eqs. (11) and (12) are not independent of one another. In fact, as $r_f=\theta_f i-\pi$ and as T_M and T_F are functions of F and M these equations imply that, in addition to λ, there is another effect through which inflation can affect the wedge between the marginal product of capital and the firm's real net rate of interest r_f. The precise nature of this effect will be analyzed in section 5 [see eq. (32)]. For the time being it suffices to realize that an increase in the nominal rate of interest due to inflation reduces the desired stock of real balances with any given stock of capital and thus increases the marginal transactions cost T_F. Obviously this reduces the real net rate of interest r_f that satisfies (12), even when true economic depreciation is allowed and the wedge from historical cost accounting is absent.

The firm's optimization conditions will henceforth be interpreted as domestic equilibrium conditions that implicitly determine the relationship between the interest rates, the inflation rate, and the aggregate stocks of capital and money balances. The reduction in the stock of real balances that inflation induces with any given level of capital will thus be seen as a macroeconomic equilibrium phenomenon. It is assumed that the anticipated inflation rate π equals the growth rate of the nominal stock of money and that a comparative static change in this growth rate produces an unforeseen initial jump in the price level to adjust the stock of money balances to the level demanded by the firms. This jump implies unforeseen jumps in three of the four state variables of the firm (A, B, M), but the validity of eqs. (11) and (12) from which the allocative results of this paper will be derived is not affected.

3. Inflation and international capital movements

The present section addresses the question of how an increase in the rate of inflation in one country affects the equilibrium allocation of capital in the world economy. It assumes a given aggregate stock of capital and studies inflation-induced changes in its structure.

The question of how inflation affects the national savings flow and the capital flows nourished thereby is not discussed. To be sure, savings-induced capital movements can be important for the direction of long run capital movements. However, there can be little doubt that, in the short and medium run, capital movements resulting from the attempt to restructure a given aggregate stock of capital are far more important than capital movements resulting from diverging national savings flows. Moreover, the subsequent analysis will show that the direction of cross border savings flows is ambiguous, since the increase in one country's inflation rate reduces *all* countries' real net rates of interest. While this reduction will result in a world-wide decline in the volume of savings, there are no obvious asymmetries in the magnitudes of the respective national reductions in savings from which the direction of savings-induced capital movements could easily be derived. By way of contrast, it will be shown that unilateral changes in the rate of inflation will result in unambiguous reallocations of the existing world capital stock.

Assume that capital is mobile and labor immobile. In the absence of inflation and taxation, market forces will allocate any given world capital stock among the different countries such that the marginal product of capital, net of transactions costs and depreciation, is the same everywhere. World output, net of transactions costs and depreciation, is maximized, given the respective national stocks of real money balances firms wish to hold at the equilibrium interest rate. Let X and Y indicate the domestic and the foreign country in a two-country case and i the uniform world interest rate. Then it holds that

$$F_K^X(1-T_F^X)-\delta^X=i=F_K^Y(1-T_F^Y)-\delta^Y. \tag{15}$$

This condition does not characterize a Friedman-type optimum optimorum. In such an optimum, the marginal savings of transactions costs through money holding, and hence the nominal rate of interest, would have to be zero in each country $(-T_M^X=-T_M^Y=i=0)$ and the net marginal products of capital would have to equal the common level of the national deflation rates: $F_K^X(1-T_F^X)-\delta^X=-\pi=F_K^Y(1-T_F^Y)-\delta^Y$. Nevertheless, condition (15) can be taken as a reference point for the analysis to follow. The question is how is this condition affected by the interaction of inflation and taxation and what are the implications for the international allocation of capital?

To concentrate on differences in inflation rates and the resulting distortions, asset holders are assumed to face identical tax rates in the two countries.[9] Moreover, the asset holders, whose domestic arbitrage behavior was described by (5) and used to derive the market value function (7), are also assumed to be the ones engaged in international arbitrage. One may think of private households or institutions specializing in portfolio optimization. The portfolio includes domestic bonds, domestic shares, foreign bonds, and foreign shares. An equilibrium occurs when the portfolio holders are indifferent between the four assets and when all net rates of return are the same.

Of course the rates of return include the capital gains from currency appreciation. Assume flexible exchange rates and purchasing power parity. In this case, the capital gains per unit of capital invested are $\pi^X-\pi^Y$ for an investor of Country X and $\pi^Y-\pi^X$ for an investor of Country Y. It is assumed that the currency gains are taxed at the rate τ_c which also applies to the gains from share appreciation. A modification of this assumption will be considered below. The net currency gains are therefore $(\pi^X-\pi^Y)\theta_c$ or $(\pi^Y-\pi^X)\theta_c$. respectively, and the investors of both countries are indifferent between domestic and foreign assets if[10]

[9]With no change in the formal results to be derived, this assumption can be relaxed by allowing for different capital gains (τ_c), interest (τ_a), and dividend (τ_d) tax rates. It is sufficient to assume identical profit tax rates for then it follows from the characteristics of the Miller equilibrium (10) that θ_a/θ_c is the same in both countries, and condition (17) below continues to hold. With differing profit tax rates, on the other hand, it would be necessary to assume imperfect substitutability between domestic and foreign assets in order to avoid implausible corner solutions. The firms' national real net rates of interest r_f^X and r_f^Y would be defined as before and the relationship between these rates and the respective national stocks of capital would still be determined by (12). Eq. (17) would no longer be true, but as long as wealth owners react to an increase in $r_f^Y-r_f^X$ by rearranging their portfolios towards assets of Country Y, the direction of real international capital flows would be the same as that illustrated in fig. 1 below.

[10]In line with the OECD Model Double Taxation Convention of 1977 and a common practice among OECD countries it is assumed that the residence country offers credit for the source country's withholding taxes on border-crossing interest income flows. It can be left open whether there is an international double taxation relief for border-crossing dividend flows. When there is such a relief, (16) implies that each investor is indifferent between all four types of asset. When there is none, no shares from non-resident countries are included in the portfolios but nevertheless (16) and all following equations continue to hold.

$$i^X \theta_a = i^Y \theta_a + (\pi^X - \pi^Y)\theta_c \quad \text{(international equilibrium)}, \tag{16}$$

where θ_a is the interest income tax factor introduced before. Using (1) and the condition for a Miller equilibrium, (10), this equation can also be written as

$$r_f^X = r_f = r_f^Y, \tag{17}$$

and it becomes apparent that arbitrage equates the firms' real net rates of interest.

The international structure of the world capital stock $\bar{K}$ is determined such that the national demands for capital exhaust this stock,

$$\bar{K} = K^X + K^Y,$$

that equilibrium condition (17) holds, and that the firms' optimality conditions are satisfied. From (1) and (11) we have

$$r_f + \pi^Z = -\theta_f T_M^Z(F^Z, M^Z), \tag{18}$$

and, as $\gamma = \delta$ by assumption, from (12) and (13):

$$r_f = \theta_f [F_K^Z(1 - T_F^Z) - \delta^Z] - \pi^Z \lambda^Z (1 - \alpha^Z), \qquad \text{where in} \tag{19}$$

$$\lambda^Z = \frac{\tau_f \delta^Z}{r_f + \delta^Z + \pi^Z(1 - \alpha^Z)},$$

and the superscript $Z = X, Y$ indicates variables that are country-specific.

Eqs. (19) implicitly define each country's demand for capital K^Z as a function of r_f, π^Z, and M^Z, and eqs. (18) define M^Z as a function for each country of K^Z, r_f, and π^Z. Taken together, the two sets of equations therefore define an implicit function $\Phi^Z(\pi^Z, r_f, K^Z) = 0$ that determines this country's capital demand, given π and r_f, or its real net rate of interest, given π and K. Differentiating (18) and (19) at $\pi^X = \pi^Y = 0$ and recalling that $F_K, T_{MM}, T_{MM}T_{FF} - T_{FM}^2 > 0$, T_{FM} $(= T_{MF}) < 0$, and $F_{KK} < 0$ by assumption, the properties of Φ for small inflation rates can be derived straightforwardly:

$$\Phi_{r_f}^Z = -\theta_f F_K^Z T_{FM}^Z \left.\frac{\partial M^Z}{\partial r_f}\right|_{\pi, K} - 1$$

$$=\frac{F_K^Z T_{FM}^Z}{T_{MM}^Z}-1<0, \tag{20}$$

$$\Phi_\pi^Z=-\theta_f F_K^Z T_{FM}^Z \left.\frac{\partial M^Z}{\partial \pi}\right|_{r_f,K}-\lambda^Z(1-\alpha^Z)$$

$$=\frac{F_K^Z T_{FM}^Z}{T_{MM}^Z}-\lambda^Z(1-\alpha^Z)<0, \tag{21}$$

$$\Phi_K^Z=\theta_F\left[F_{KK}^Z(1-T_F^Z)-\frac{F_K^{Z2}}{T_{MM}^Z}(T_{FF}^Z T_{MM}^Z-T_{FM}^{Z2})\right]<0,\ Z=X,Y. \tag{22}$$

Obviously the signs of (20) and (22) imply that, despite the interaction of money holding and transactions costs, each country's capital demand is a well-behaved function of the firms' real net rate of interest,

$$\left.\frac{\mathrm{d}K^Z}{\mathrm{d}r_f}\right|_\pi=-\frac{\Phi_{r_f}^Z}{\Phi_K^Z}<0,$$

and the signs of (21) and (22) similarly imply that the demand curves shift inward as a reaction to inflation

$$\left.\frac{\mathrm{d}K^Z}{\mathrm{d}\pi^Z}\right|_{r_f}=-\frac{\Phi_\pi^Z}{\Phi_K^Z}<0, \qquad Z=X,Y. \tag{23}$$

Inflation therefore unambiguously induces a capital export.

The result is illustrated by the Kemp diagram shown in fig. 1. The distance between the verticals of this diagram is the world capital stock. The employment of capital in the domestic country (X) is measured from left to right, while that of the foreign country (Y) is measured from right to left. Accordingly, the downward sloping curves represent domestic, and the upward sloping curve, foreign demand for real capital. The demand curves are the graphs of the right-hand side of (19) where, for any given value of r_f,

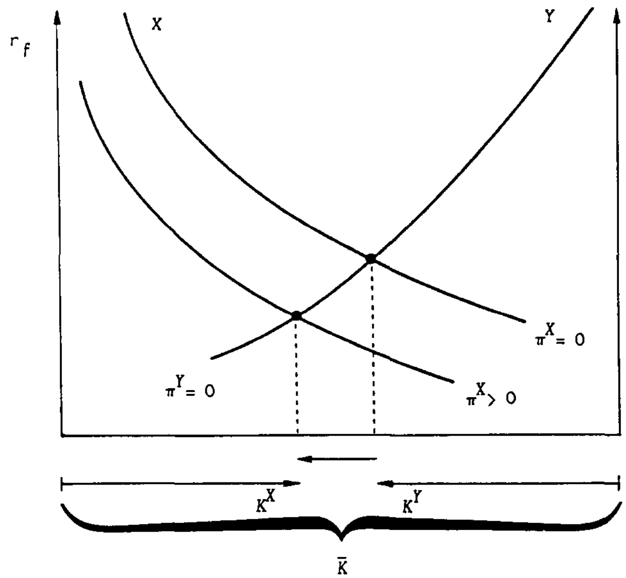

Fig. 1. Inflation and international capital movements.

the stock of real money balances is determined according to (18) and where it is alternatively assumed that $\pi^X = \pi^Y = 0$ and $\pi^X > \pi^Y = 0$.

4. Discussion and comparison with alternative approaches

The previous section analyzed the problem of inflation-induced capital movements under assumptions that arguably can be called 'realistic'. This section discusses alternatives.

As can be seen by inspecting the numerator of the right-hand side of (23) specified in (21), the model provided two reasons for the flight of capital from the inflating country. One is captured by the term $F_K T_{FM}/T_{MM}$ which reflects the fact that, given domestic capital and output, inflation reduces the demand for real balances, and in turn increases the frictions associated with the production process. The other comes through λ, the internal present value of depreciation allowances. With historical cost accounting ($\alpha = 0$), inflation erodes this value and imposes a burden on capital. Both the increased friction through a reduced stock of money balances and the additional real tax burden through historical cost accounting expel the capital, and each of these reasons remains operative even when the other is absent.

This contrasts with a paper by Hartman (1979) where it is argued that inflation unambiguously induces a capital import. Hartman's finding cannot be produced with the model as specified in the last section. At best, when transactions costs are negligibly small and depreciation allowances are fully indexed ($\alpha=1$), we have $\Phi_\pi^Z \approx 0$, so that inflation is neutral with regard to the world structure of capital.

Hartman considers a different economy without transactions costs and historical cost accounting and he assumes that capital gains from currency appreciation are fully taxed. His paper does not incorporate a model of a firm and there are no corporate shares and so no taxes on capital gains from these shares. Under these circumstances, there may indeed be a capital import into the inflating country.

To see this assume that, in addition to τ_c, there is a tax rate τ_c^* and a corresponding tax factor $\theta_c^* \equiv 1-\tau_c^*$ that is exclusively applied to currency appreciation. In this case, the international arbitrage condition (16) is replaced by

$$i^X\theta_a = i^Y\theta_a + (\pi^X - \pi^Y)\theta_c\theta_c^*. \tag{24}$$

Substituting $i^Z = (r_f^Z + \pi^Z)/\theta_f$, $Z = X, Y$, according to (1), this equation can be transformed to

$$r_f^X + \pi^X\left(1 - \theta_c^* \frac{\theta_f\theta_c}{\theta_a}\right) = r_f^Y + \pi^Y\left(1 - \theta_c^* \frac{\theta_f\theta_c}{\theta_a}\right), \tag{25}$$

or, when the Miller condition (10) is used, to

$$r_f^X + \tau_c^*\pi^X = r_f^Y + \tau_c^*\pi^Y. \tag{26}$$

Eq. (26) shows that with $\tau_c^* > 0$ there is no longer a tendency for the firms' real net rates of interest to be equal. Instead, domestic inflation will reduce the domestic firms' real net rate of interest below that of foreign firms.

Assume now that there are no transactions costs ($T_F^Z = 0$) and that depreciation allowances are fully indexed ($\alpha = 1$). Then, (18) becomes irrelevant and (19) simplifies to Hartman's equation

$$r_f^Z = \theta_f(F_K^Z - \delta^Z), \qquad Z = X, Y. \tag{27}$$

Inserting this into (26) yields

$$\theta_f(F_K^X - \delta^X) + \tau_c^*\pi^X = \theta_f(F_K^Y - \delta^Y) + \tau_c^*\pi^Y. \tag{28}$$

For the case $\tau_c^* > 0$, eq. (28) implies Hartman's result that, after a rise in π^X, a lower value of F_K^X and a higher value of F_K^Y is required. Thus inflation attracts capital when the tax system is fully indexed, when there are no transactions costs, and when capital gains from currency appreciation are taxed *more* heavily than capital gains from share appreciation.

Modifications of Hartman's model were recently studied in a paper by Sörensen (1986). Assuming debt financing, full indexing ($\alpha=1$), and no transactions costs, Sörensen demonstrated that inflation will induce a capital export when the tax on capital gains from currency appreciation is negligible and the personal tax rate on interest income exceeds the corporate tax rate. When there is a Miller equilibrium [eq. (10)], this case corresponds to setting $\tau_c^* < 0$ in (28); i.e., to assuming that capital gains from currency appreciation are taxed *less* heavily than capital gains from share appreciation.

To avoid this asymmetry, it would be necessary to assume that there is no special capital gains tax on currency appreciation ($\theta_c^* = 1$), that there is no, or only a low, general capital gains tax such that $\theta_f \theta_c > \theta_a$, and that there is no longer a Miller equilibrium. As can be seen from (25), this would indeed imply that, with any given values of the foreign variables r_f^Y and π^Y, domestic inflation will increase the firms' real net rate of interest r_f^X and, provided (27) is still correct, there would be a capital export. It is important to note, however, that this constellation of tax rates induces the firm never to pay out any dividends. This not only creates serious existence problems,[11] but also implies that shareholders have very small personal tax bases, which in turn makes it implausible to assume that the marginal personal tax rate *exceeds* the corporate tax rate.

Asymmetries in the taxation of capital gains, the lack of a motive for money holding, and the assumption of indexed tax systems would therefore seem to be responsible for the predictions on inflation-induced capital movements generated by the Hartman–Sörensen model.

5. Inflation and the rate of interest

It is obvious from the findings summarized in fig. 1 that domestic inflation reduces the real net rate of interest for any given level of the world capital stock. Depending on the slopes of the national capital demand curves, this reduction will be between zero and the size of the downward shift of the domestic capital demand curve. The following two sections study the implications of these two extreme possibilities for Fisher's problem of the extent to which inflation translates into *nominal* interest rates. They thus limit the scope for inflation-induced adjustments in the nominal rate of interest that are possible in the present model.

[11]Cf. Sinn (1987a, ch. 5.3.4).

5.1. The small-country case

A constant real net rate of interest can be associated with the limiting case where the domestic country is infinitely small, i.e., where the capital driven out by inflation is negligible relative to the aggregates of the rest of the world (capital, labor, output, money balances) and therefore cannot affect the interest rates abroad. Differentiating (24) for constant values of i^Y and π^Y gives

$$\frac{\mathrm{d}i^X}{\mathrm{d}\pi^X}=\frac{\theta_c\theta_c^*}{\theta_a} \quad \text{(small country).} \tag{29}$$

It has recently been shown by Hansson and Stuart (1986) that $\mathrm{d}i^X/\mathrm{d}\pi^X=1$ if the capital gains from currency appreciation are taxed at the same rate as domestic interest income. This result is confirmed by (29) when $\theta_c\theta_c^*=\theta_a$.[12] It would also follow from Hartman's model for he too assumed that capital gains and interest income tax rates are equal. By way of contrast, Sörensen's assumption that capital gains taxes are negligible implies that $\mathrm{d}_i^X/\mathrm{d}\pi^X=1/\theta_a>1$.

The neglect of capital gains taxation is appropriate for continental Europe, but not for the Anglo-Saxon countries. The United States now includes all realized capital gains in the personal tax base. On the other hand, it has to be stressed that the capital gains tax rates modeled here and in the previous literature must be interpreted as equivalent effective tax rates on accrued capital gains which, because of deferred realization, are smaller than those on realized capital gains defined in the tax law. In a somewhat different context, Fullerton, King, Shoven and Whalley (1981, p. 684) have argued that, taking the usual holding periods of assets into account, the equivalent effective capital gains tax rate is only 50% of the tax rate on realized capital gains. This suggests that it should typically be expected that

$$1<\frac{\mathrm{d}i^X}{\mathrm{d}\pi^X}<\frac{1}{\theta_a} \quad \text{(small country).} \tag{30}$$

The present model confirms this expectation, but with arguments that derive from a comparison of the international and the domestic capital market equilibria. If the domestic capital market is in a Miller equilibrium and the tax system treats capital gains from share and currency appreciation symmetrically, then $\theta_a=\theta_c\theta_f$ and $\theta_c^*=1$. Eq. (29) therefore reduces to

[12] The composition of the basic capital gains tax (θ_c) and the 'currency gain surcharge' (θ_c^*) can be left open here because the taxation of capital gains from shares does not matter when the country is small.

$$\frac{\mathrm{d}i^X}{\mathrm{d}\pi^X}=\frac{1}{\theta_f} \quad \text{(small country).} \tag{31}$$

Obviously, when there is both a corporate tax and a general capital gains tax (θ_f, $\theta_c<1$), this equation implies (30). Coincidentally, (31) is the same equation which Feldstein (1976) derived from a closed-economy growth model with taxation and indexed depreciation allowances.[13]

5.2. The large-country case

While the small-country case is appropriate for many countries, it is not so for all. Empirical findings in large countries suggest that inflation raises the nominal rate of interest by less than 100% of the increase in the rate of inflation.[14] To understand this phenomenon, consider the other extreme where the economy is closed or large enough to face an inelastic foreign demand curve for real capital. In this case, it follows from (20) and (21) in conjunction with $\mathrm{d}r_f/\mathrm{d}\pi^X|_K=-\Phi_\pi^X/\Phi_{r_f}^X$ that

$$\frac{\mathrm{d}r_f}{\mathrm{d}\pi^X}=-\frac{\lambda^X(1-\alpha^X)+F_K^X/\mu^X}{1+F_K^X/\mu^X}<0 \quad \text{(large country).} \tag{32}$$

Here, from (11) and $T_{MF}=T_{FM}$.

$$\mu^X\equiv\left.\frac{\mathrm{d}F^X}{\mathrm{d}M^X}\right|_i=-\frac{T_{MM}^X}{T_{MF}^X}$$

is the marginal velocity of money holding. Noting that $r_f=i^X\theta_f-\pi^X$ implies $\mathrm{d}i^X=(\mathrm{d}r_f+\mathrm{d}\pi^X)/\theta_f$ and that (1) and (12) imply $F_K=(i+\delta)/(1-T_F)$ at $\pi=0$,

$$\frac{\mathrm{d}i^X}{\mathrm{d}\pi^X}=\frac{1-\lambda^X(1-\alpha^X)}{\theta_f\left(1+\dfrac{i^X+\delta^X}{(1-T_F^X)\mu^X}\right)} \quad \text{(large country)} \tag{33}$$

can be derived from (32).

In the special case where depreciation allowances are fully indexed ($\alpha^X=1$) and the marginal velocity of money holding approaches infinity ($\mu^X\to\infty$),

[13] Cf. also Darby (1975) and Tanzi (1976).

[14] See Hansson and Stuart (1986, p. 1331) for an overview of the empirical literature and Summers (1983) for a recent example.

(33) coincides with eq. (31); and with historical cost accounting and an infinite marginal velocity ($\alpha^X=0$, $\mu^X\to\infty$), eq. (33) reduces to $\mathrm{d}i/\mathrm{d}\pi=(1-\lambda)/\theta_f$, a result first reported in Feldstein, Green, and Sheshinski (1978). In general, however, (33) reveals that the impact of inflation is lower than in either of these cases, as $(i+\delta)/[(1-T_F)\mu]>0$.

The impact can even be smaller than the Fisher effect. This is definitely so, for example, when there are no taxes ($\tau_f=\lambda^X=0$), for then (33) becomes

$$\frac{\mathrm{d}i^X}{\mathrm{d}\pi^X}=1\Bigg/\left[1+\frac{i^X+\delta^X}{(1-T_F^X)\mu^X}\right]<1 \quad \begin{array}{c}\text{(large country, no taxation}\\ \text{and/or short-lived assets).}\end{array} \tag{34}$$

Inflation increases the nominal rate of interest and thus reduces the stock of real money balances that firms wish to hold. This increases the total and marginal transactions costs and reduces the real net rate of interest that the existing stock of real capital is able to pay. A less than full adjustment of the nominal interest rate results.

With taxation, such a result is no longer assured, but it is still possible. This is particularly true with short-lived real assets, since with such assets the burden of historical cost accounting would be maximal.[15] For short-lived assets we know from (14) that $1-\lambda^X\approx\theta_f$ and thus (32) would still apply. But of course, longer asset lives may be realistic. In the case $\gamma<\infty$ it follows from (13) and (14) that $1-\lambda^X>\theta_f$ and thus both the cases $\mathrm{d}i/\mathrm{d}\pi^X<1$ and $\mathrm{d}i/\mathrm{d}\pi^X>1$ can occur. A less than full transformation of inflation into nominal interest rates remains possible and, contrary to what Fisher believed, it is not in itself an indication that people suffer from money illusion.

There have been other explanations for $\mathrm{d}i/\mathrm{d}\pi<1$ in the literature, the most prominent ones being those of Mundell (1963) and Tobin (1969). Both explanations rely on the Pigou effect, i.e., the fact that the decline in the stock of real balances resulting from the rise in the nominal rate of interest stimulates private savings with any given real rate of interest. In Mundell's model, the flow of investment – the time derivative of capital – is a falling function of the real rate of interest. An inflationary equilibrium requires a reduced real rate of interest in order to raise investment to the increased savings level. In Tobin's model, the stock of capital is a falling function of the real rate of interest or vice versa. Over time, the increase in savings drives the economy to a new steady state with a higher capital intensity and hence a lower real rate of interest.[16]

[15]That inflation hurts short-lived assets more than long-lived ones was first pointed out by Auerbach (1979). Cf. Boadway, Bruce and Mintz (1984) for a related empirical study of inflation-induced changes in the cost of capital of different categories of assets.

[16]The empirical validity of the Tobin–Mundell effect has been called into question by Feldstein (1976) and Summers (1983).

There is a fundamental difference between these explanations and the one presented in this paper. The Tobin–Mundell effect implies a less than full adjustment of the nominal interest rate because inflation stimulates capital formation and because there are no taxes. By contrast, in the present model an imperfect adjustment of the nominal interest rate is due to the fact that the existing capital stock can no longer bear the pre-inflation real net rate of interest because the reduction of the stock of real balances increases the frictions in the production process and because the interaction of inflation and historical cost accounting increases the real tax burden. In short: while the Mundell–Tobin effect implies an *increase in the (flow) supply of capital*, the transactions costs and taxation effects analyzed here result in a *reduction in the (stock) demand for capital*. The three effects have different implications for the size of the domestic stock of capital. However, despite the differences, they affect international capital movements in a similar way as both the increase in the domestic supply of, and the reduction in the domestic demand for, capital result in capital exports.

Yet another explanation for an imperfect adjustment of interest rates has been given by Fried and Howitt (1983). In their model, bonds are imperfect substitutes for real capital and close substitutes for money, producing similar liquidity yields. Thus, the reason that accounts for the increase in the wedge between the rates of return on real capital and bonds in the Fried–Howitt model is the same as the one which makes inflation create a wedge between the rate of return on bonds and money in the present model; that is, which makes inflation increase the *nominal* rate of interest. The present model neglects the Fried–Howitt effect since it follows Fisher's assumption that bonds and real capital are perfect substitutes. The reason why, in the absence of taxation and with a given capital intensity in production, inflation is nevertheless able to reduce the real rate of interest is simply that, because of the reduction in money holding, it increases the marginal transactions cost and hence reduces the real interest rate that a given stock of capital can bear.

The Fried–Howitt and Mundell–Tobin effects complement the two effects studied in this paper by producing an additional inflation-induced downward shift in the domestic capital demand curve in fig. 1 and by increasing the domestic flow supply of capital, respectively. They strengthen the case for non-adjustment of interest rates and create an even higher volume of capital exports.

6. Conclusions

This paper has analyzed the significance of inflation for international capital movements, concentrating on the effects of transactions costs and taxation with historical cost accounting. Assuming a Miller equilibrium and equal tax rates on capital gains from share and currency appreciation, it was shown that domestic inflation imposes a burden on domestic capital, driving part of it out of the country. Despite flexible exchange rates, costless arbitrage, and perfect foresight, inflation brings about domestic disinvestment and capital exports.

The result contradicts previous findings based on models with no motive for money holding and with indexed tax systems. It also contradicts the popular belief, cited in the introduction, that inflation necessarily stimulates capital formation when the nominal interest rate rises less than the inflation rate. This belief rests on the assumption that inflation increases the supply of capital. In the present model, inflation instead reduces the demand for capital. This reduction explains both the domestic disinvestment and the possibility of a less than full adjustment of interest rates.

Some caution is necessary when the results of this paper are used to interpret time series data. All calculations are based on the assumption of a given tax system and passive government behavior. As mentioned earlier, however, governments often try to compensate for the inflationary distortions by introducing investment incentives. Thus, for example, to explain why Canada had high inflation and a capital outflow in the late 1970s one would have to take into account not only that inflation rose relative to her trading partners' rates but also that, at the same time, Canadian corporations were given various tax advantages including accelerated depreciation. Without these tax advantages, capital outflow would have been greater and Canadian interest rates lower than they actually were.

On the other hand, the model makes it also clear that the impact of inflation on international capital movements cannot be assessed simply by looking at the change in the cost of capital. Even if this cost remained constant because of the introduction of countervailing investment incentives, inflation would be non-neutral as it reduces the demand for real balances which then increases the transactions costs in the economy. Clearly, inflation continues to expel the capital even when government neutralizes the taxation effects.

Appendix

This appendix derives the optimality conditions for money holding and real investment using eqs. (2), (3), (4), and (8).

The general optimality condition $\partial\mathscr{L}/\partial\dot{M}=0$ implies that

$$\lambda_M=\frac{\theta_d}{\theta_c}, \tag{A.1}$$

and it follows from this result and the canonical equation for M, $\dot{\lambda}_M-\lambda_M[(i\theta_a/\theta_c)-\pi]=-\partial\mathscr{L}/\partial M$, that

$$i\,\frac{\theta_a}{\theta_c} = -\theta_f T_M. \tag{A.2}$$

Because of (10), this is equivalent to

$$i = -T_M. \tag{A.3}$$

Similarly, it follows from $\partial\mathscr{L}/\partial\dot{K}=0$ that

$$\lambda_K + \lambda_A = \frac{\theta_d}{\theta_c} \tag{A.4}$$

or, as the tax factors are constants,

$$\dot{\lambda}_K + \dot{\lambda}_A = 0. \tag{A.5}$$

Using (9) and once again (2), (3), and (4), the canonical for K and A, $\dot{\lambda}_x - \lambda_x[(i\theta_a/\theta_c) - \pi] = -\partial\mathscr{L}/\partial x, x = K, A$, can be specified as

$$\dot{\lambda}_K - \lambda_K r_f = -\frac{\theta_d}{\theta_c}\{\theta_f[F_K(1-T_F)-\delta] - \tau_f\delta\} - \lambda_A\delta, \qquad \text{and} \tag{A.6}$$

$$\dot{\lambda}_A - \lambda_A r_f = -\frac{\theta_d}{\theta_c}\tau_f\gamma + \lambda_A[\gamma + \pi(1-\alpha)]. \tag{A.7}$$

Adding these two equations and using (A.4) and (A.5) gives

$$r_f = \theta_f[F_K(1-T_F)-\delta] + (\gamma-\delta)(\tau_f - \lambda) - \lambda\pi(1-\alpha), \qquad \text{where} \tag{A.8}$$

$$\lambda \equiv \lambda_A\,\frac{\theta_c}{\theta_d}. \tag{A.9}$$

By definition it holds that $\lambda_A(t) = \partial V(t)/\partial A(t)$. Noting that (3) implies $\partial A(u)/\partial A(t) = \exp\int_t^u -[\gamma + \pi(x)(1-\alpha)]\,\mathrm{d}x$, the expression

$$\lambda_A(t) = \int_t^\infty \frac{\theta_d}{\theta_c}\tau_f\gamma\left[\exp\int_t^u -r_f(x) - \gamma - \pi(x)(1-\alpha)\,\mathrm{d}x\right]\mathrm{d}u \tag{A.10}$$

can be derived from (4) and (7). When r_f and π are constants, it follows that $\lambda_A = (\theta_d/\theta_c)\tau_f\gamma/[r_f + \gamma + \pi(1-\alpha)]$ or, equivalently, that

$$\lambda = \frac{\tau_f \gamma}{r_f + \gamma + \pi(1-\alpha)}. \tag{A.11}$$

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