Metlzer's Paradox and the Optimum Tariff in a Monetary Economy

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Abstract

We augment the standard two country, two-commodity and two-factor trade model by allowing for money to exist as an additional asset. We find that it is possible for an increase in the domestic tariff to worsen the terms of trade if the importable sector is severely distorted by the existence of money. Moreover, the Metzler condition is no longer both necessary and sufficient to rule out the Metzler paradox. Finally, we show that the conventional formula for the optimum tariff, derived in barter trade models, has a downward (upward) bias if money is more (less) efficacious in the importable sector. "In the real world there is no simple dividing line between trade and monetary issues." ⟨Krugman and Obstfeld [1994], p. 8.⟩ (JEL Classification: F11, E40)

I. Introduction

Most of the results in international trade theory have been derived within a barter framework. It has been shown, however, that the introduction of money can alter results obtained within a non-monetary framework. For instance, the dictum of classical trade theory that, for a small open economy, an improvement in the terms of trade is beneficial does not, in general, hold in the case of a monetary economy ⟨see Kemp [1990] and Palivos and Yip [1996]⟩.[1]

There has been some work in the literature on the effects of a tariff within a general equilibrium model of money ⟨notably, Anderson and Takayama [1978 and 1981], Batra and Ramachandran [1980]⟩. These papers have indubitably generated useful insights in the analysis of nominal issues, such as the effects of a tariff on the domestic price level, the nominal exchange rate and the balance of payments. However, for analytical convenience, most of these papers assume that commodities and money enter separably in the utility function, which results in the classical dichotomy between the real and the monetary sector. These monetary models behave therefore very similarly to standard barter trade models. For instance, Anderson and Takayama [1978 and 1981] confirm that for a stable system, where the Marshall-Lerner condition is satisfied, the Metzler condition is necessary and sufficient to rule out the Metzler paradox, a result shared with standard barter trade models.

In this paper we augment the two country, two-commodity and two-factor model developed by Jones [1969], by allowing for money to exist as an additional asset.[2] In particular, we introduce a general cash-in-advance constraint ⟨see, for example, Stockman [1981]⟩ in which money is not equally effica-

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1. Other examples include Drabicki and Takayama [1983] and Stockman [1985]. Drabicki and Takayama show that the theory of comparative advantage breaks down in a monetary world under fixed exchange rates when the balance of payments is not in equilibrium. Similarly, in a real trade model with transactions-based demand for money, Stockman shows that changes in inflation can cause changes in the pattern of trade even in the absence of real changes in comparative advantage.
2. See Choi and Yu [1987] for the adoption of the Jones model to study the effects of tariffs.

cious in all markets.[3] Put differently, the share of purchases which must be made using cash varies across goods (markets). This introduces a real distortion, since the marginal rate of substitution (*MRS*) is not equal anymore to the domestic price ratio, and the classical dichotomy is no longer valid. We then apply the model to analyze familiar topics in the theory of nominal tariffs such as the Metzler paradox and the effects of tariffs on the terms of trade in the context of a monetary economy. It is found that the Metzler condition is not both necessary and sufficient to rule out the Metzler paradox, contrary to the conventional conclusion obtained in barter trade models. Moreover, we re-derive the formula for computing the optimum tariff in the presence of monetary distortions and provide an intuitive economic interpretation. We find that the standard optimum tariff formula derived in barter trade models understates (overstates) the true one if money is more (less) efficacious in the importable sector.

The organization of the paper is as follows. Section II provides a detailed description of the basic model and Section III characterizes the terms-of-trade effects of tariffs. Section IV explores the effects of a tariff on the domestic price ratio and discuss the possibility of the Metzler paradox. Section V derives the optimum tariff formula for a monetary economy. Finally, Section VI concludes the paper.

II. The Model

Imagine two countries – Home and Foreign – which operate under a floating exchange rate regime. Both countries are large enough to influence the international prices by manipulating their volume of trade. Each country produces and consumes two internationally traded commodities, named 1 and 2. We use D and X to denote, respectively, demand and production. Thus, D_1 indicates the home country's demand for good 1, and X_2^* the foreign country's production of good 2. The asterisk, "*", symbolizes variables

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3. Kemp [1990] adopts a static, money-in-the-utility-function (MIUF) model to examine the welfare effects of free trade for small monetary economies. However, due to the generic nature of the MIUF approach, it is difficult to uncover the underlying economic forces that drive his conclusion. We, therefore, employ the CIA model which highlights the transactions motive for the money demand.

for the foreign country. Furthermore, the price of commodity j in the home (foreign) country is denoted by P_j (P_j^*), $j = 1, 2$.

If we let M denote the stock of money demanded, $\bar{M}$ the given stock of money, and S a monetary transfer/tax, then the budget constraint for a representative agent in the home country can be written as[4]

$$P_1 D_1 + P_2 D_2 + M = P_1 X_1 + P_2 X_2 + \bar{M} + S. \tag{1}$$

In addition to the budget constraint, (1), the representative agent faces the following cash-in-advance (henceforth, CIA) or liquidity constraint

$$\phi_1 P_1 D_1 + \phi_2 P_2 D_2 \leq M, \tag{2}$$

where $\phi_j \in [0, 1]$, $j = 1, 2$, denotes a constant share of purchases of good j. This CIA constraint requires the individual to hold money balances sufficient to finance at least a certain part of her consumption purchases.[5] In general, consumption of one good requires larger cash balances, per unit of value, than consumption of the other good and hence $\phi_1 \neq \phi_2$.[6]

The specification $\phi_1 \neq \phi_2$ is crucial to our analysis and merits further discussion and justification. First, the assumption $\phi_1 \neq \phi_2$ can be considered as the outcome of existing regulations regarding the terms of payments of imports and the obtaining and use of credit (foreign and domestic) to finance imports ⟨see Laird and Yeates [1990]⟩. For instance, different exchange rates may apply to imports and exports, and there are import surcharges and advance import deposits. The existence of these institutional arrangements is confirmed by the study of Roningen [1978] who constructs

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4. According to (1), the government plays only a passive role in the economy by redistributing the seigniorage back to the representative agent in a lump-sum fashion.

5. It is assumed that all transactions in the goods market involve seller's money [see Helpman and Razin [1984] for a discussion on different payment systems within a one-good framework]. Moreover, both domestic and foreign supply are assumed to be constant throughout the analysis.

6. This formulation of the CIA constraint is slightly more general than the one considered in Stockman [1981], where $\phi_j = 1$, $j = 1, 2$, as well as the one adopted in Lucas and Stokey [1987], where there are two types of goods, pure cash goods with $\phi = 1$ and pure credit goods with $\phi = 0$. Indeed, our formulation of the general CIA constraint can be re-interpreted as modeling the differences in the use of credit financing in goods purchases.

a general restriction index and shows that "country practices restricting exchange rates, trade, and payments do affect trade flows among OECD countries" (p. 475). Specifically, the general restriction index coefficients of the regression equation are "statistically significant at the 95% level in 9 out of 14 cases" (p. 473). Second, it can also be viewed as the outcome of existing export credits. Table 1 provides statistical evidence on the difference of export credits across sectors. Third, one can actually view D_1 and D_2 as being composite goods consisting of different proportions of both non-durables goods and flow services of durables. Since the non-durable goods are subject to a different degree of credit rationing rather than the durables, one can expect $\phi_1 \neq \phi_2$.[7] Fourth, empirical evidence found in Cramer and

Table 1a
Developing Countries' Outstanding Trade Credits as a Percentage of 1987 Exports

Traditional exports	16.7
Non-traditional exports, of which	
– capital goods	30.0
– consumer durables	17.7
– other manufactures	44.0
Total	81.9

Table 1b
Average Maturity of Trade Credits (months) in Selected Developing Countries

Traditional exports	1.9
Non-traditional exports, of which	
– capital goods	48.4
– consumer durables	2.1
– other manufactures	5.2

Notes : Non-traditional goods refer mainly to manufactured goods excluding steel, fertilizers, pulp and paper, which have been traditionally traded on the same basis as primary commodities. They include consumer durables, capital goods and other manufactures.

Source : UNCTAD [1992].

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7. A similar argument can be made with regard to necessary and luxury goods.

Reekers [1976] indicates that the ratio of currency and demand deposits to turnover/sales varies considerably from one sector to another. They find that this liquidity ratio is positively related to the share of value added in turnover. We report their findings in Table 2. This provides additional support for the assumption $\phi_1 \neq \phi_2$. Finally, notice that if $\phi_1 = \phi_2 = \kappa(\kappa \in [0, 1])$, then the velocity of circulation, defined as $V \equiv [P_1D_1 + P_2D_2]/\bar{M} = [P_1D_1 + P_2D_2]/[\phi_1P_1D_1 + \phi_2P_2D_2] \, (= 1/\kappa)$, is constant and, in particular, independent of all other economic variables, such as the interest rate and the level of income. This, however, contradicts the empirical evidence found in a series of papers ⟨see, for example, Mayor and Pearl [1984], and Palivos, Wang, and Zhang [1993]⟩.

In summary, the home country can be viewed as maximizing a utility

Table 2
Money Holdings in Percent of Sales for Selected Sectors

Sector	Currency and demand deposits
Agriculture	5.3
Construction	3.8
Electrical and metallurgical industry	2.2
Other metal manufacturing	3.6
Food processing	1.5
Textiles	2.0
Chemical industry	2.5
Water, gas and electricity	4.2
Paper and printing	4.3
Other manufacturing industry	4.0
Total manufacturing industry	2.9
Transport	5.6
Commercial services	11.7
Hospital	4.4
Other medical care	11.9
Wholesale trade	2.3
Motorcar trade	2.2
Retail trade in food	2.4
Other retail trade	2.6

Source : Cramer and Reekers [1976].

function $u(D_1, D_2)$, with respect to D_1, D_2 and M, subject to (1) and (2). The trade-off between the two goods is described by

$$\frac{u_2}{u_1} = \frac{1 + \phi_2}{1 + \phi_1} P, \tag{3}$$

where $u_i \equiv (\partial u / \partial D_i)$, $i = 1, 2$ and $P \equiv P_2/P_1$.[8]

For concreteness, but without loss of generality, let the home (foreign) country export the first (second) good and import the second (first) good. Let also t denote the tariff rate in the home country and $E_2(p, T)$ denote the home country's import demand, $i.e.$, $E_2 \equiv D_2 - X_2$, where p denotes the world relative price of good 2, $T \equiv 1 + t$ and thus $P \equiv Tp$. Simple differentiation then yields

$$\hat{E}_2 = -a\hat{p} - A\hat{T}, \tag{4}$$

where $a \equiv -(\partial E_2 / \partial p)(p/E_2)$ is the terms of trade elasticity of import demand, $A \equiv -(\partial E_2 / \partial T)(T/E_2)$ is the tariff elasticity of import demand, and a hat, "^", is used to denote relative change, that is, for any variable x, $\hat{x} \equiv dx/x$.

Using (3), the change in real income (dY) can be approximated by a change in utility, expressed in terms of the first good, as follows

$$\frac{du}{u_1} = dY = dD_1 + \frac{u_2}{u_1} dD_2 = dD_1 + \frac{1 + \phi_2}{1 + \phi_1} P dD_2 \tag{5}$$

Furthermore, the tariff revenue in the home and foreign country, expressed in terms of the first commodity, is given, respectively, by $PE_2 - pE_2$ $= (T-1)pE_2$ and $(P_1^* E_1^* - P_1 E_1^*)/P_1^* = (T^*-1)E_1^*/T^*$, where $P_1^* = (1+t^*)P_1 = T^* P_1$ is the tariff inclusive domestic price of the first commodity in the foreign country and $E_1^* \equiv D_1^* - X_1^*$ is the foreign country's import demand. We assume that the governments of both countries redistribute the tariff revenue back to the private sector in a lump-sum manner. Thus, in terms of domestic prices, aggregate spending in each country is equal to the value of its income; that is,

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8. Notice that equation (3) can emerge in a barter economy with the consumption of good i being taxed at the rate ϕ_i. The interesting thing is that exactly the same distortion arises in a monetary economy. Moreover, following standard practice in the existing literature, we assume that both D_1 and D_2 are normal goods. This then implies that the MRS [the left-hand-side of (3)] is a decreasing function of D_2.

$$D_1 + PD_2 = X_1 + PX_2 + (T-1)pE_2, \tag{6}$$

$$D_1^* + P^*D_2^* = X_1^* + P^*X_2^* + (T^*-1)E_1^*/T^*. \tag{7}$$

Consider next the home country's domestic import demand

$$E_2 = D_2(P,Y) - X_2(P). \tag{8}$$

Differentiating (8) yields

$$\hat{E}_2 = -e\hat{p} + (m/PE_2)dY - s\hat{P}, \tag{9}$$

where $e \equiv -(P/E_2)(\partial D_2/\partial P) \geq 0$ describes the substitution effect of a change in P for any given real income and $m \equiv P(\partial D_2/\partial Y)$ is the home marginal propensity to consume the importable good (good 2). In the absence of inferior goods, $1 \geq m \geq 0$. Finally, $s \equiv (P/E_2)(\partial X_2/\partial P) \geq 0$ captures the substitution effect on the production side in response to a change in P.

III. Tariffs and the Terms of Trade

As shown in the Appendix, differentiation of (6) in conjunction with (5) yields the change in real income due to a small change in the tariff rate:

$$dY = -E_2 dp + (T-1)pdE_2 + \frac{\phi_2 - \phi_1}{1+\phi_1}PdD_2. \tag{10}$$

The first term on the right-hand-side is the terms-of-trade effect. The second term indicates the income effect of a change in import demand due to the change in tariff revenue. Finally, the last term captures the novel effect due to the different degree of monetization between the two sectors. The intuition of this novel effect is straightforward. If the importable sector is less distorted by the presence of the CIA constraint ($\phi_2 < \phi_1$), then the MRS (u_2/u_1) is less than the domestic price ratio (P) according to (3). Since the MRS is a decreasing function of D_2, a drop in the consumption of the importables ($dD_2 < 0$) tends to reduce this gap of divergence between the MRS and the MRT. Thus, it is welfare improving, as implied by (10).

Furthermore, as shown also in the Appendix, substitution of (10) into (9) yields

$$\hat{E}_2 = -\mu\left\{\left[s + [e+(m/T)]\alpha^{-1}\right]\hat{p} + \left[s + e\alpha^{-1}\right]\hat{T}\right\} \tag{11}$$

where $\alpha \equiv 1 - [m(\phi_2 - \phi_1)/(1+\phi_1)] > 0$ and $\mu \equiv [1 - (mt/\alpha T)]^{-1}$ is the tariff multiplier. A comparison of (11) with (4) then suggests that

$$\alpha = \mu \{ s + [e + (m/T)]\alpha^{-1} \},$$

$$A = \mu \{ s + e\alpha^{-1} \}.$$

Under flexible exchange rates, the balance of payments must be in equilibrium which implies $\hat{p} = \hat{E}_1^* - \hat{E}_2$. Using (4) and its analogue for the foreign country, we have

$$\hat{p} = \frac{A^* \hat{T}^* - A\hat{T}}{a + a^* - 1}, \tag{12}$$

where all the variables for the foreign country are defined analogously. A stable foreign trade market requires $a + a^* > 1$ (the Marshall-Lerner condition). Thus, we conclude that

$$\frac{\hat{p}}{\hat{T}} \overset{>}{\underset{<}{=}} 0 \; iff \; A \overset{<}{\underset{>}{=}} 0.$$

In general, under normality of consumption goods, if $\phi_1 \geq \phi_2$, then the tariff multiplier is usually positive and so an increase in the tariff improves the domestic terms of trade, which is a standard result in barter trade models. However, if the monetary distortion is severe enough in the importable sector so that α is far below unity, then it is possible for the tariff multiplier to be negative; thus, the tariff deteriorates the domestic terms of trade. This result is not difficult to understand. In the case where ϕ_2 is much larger than ϕ_1, then the MRS is above P and so an increase in the consumption of importables should be called for. The increase in the tariff rate in this case exacerbates the monetary distortion which can result in a negative tariff multiplier and hence a deterioration of the terms of trade accordingly.

IV. Tariffs and the Domestic-price Ratio

Differentiating $P = pT$ yields $\hat{P} = \hat{p} + \hat{T}$ and upon utilizing (12), we obtain

$$\hat{P} = \frac{A^* \hat{T}^* + [a + a^* - 1 - A]\hat{T}}{a + a^* - 1}. \tag{13}$$

Given a foreign tariff rate, *i.e.*, $\hat{t}^* = \hat{T}^* = 0$, the elasticity of the domestic price ratio with respect to the tariff is

$$\frac{\hat{P}}{\hat{T}} = 1 - \frac{A}{a + a^* - 1} \tag{14}$$

Assuming that the Marshall-Lerner condition is satisfied, it follows from (14) that

$$\frac{\hat{P}}{\hat{T}} \stackrel{>}{_<} 1 \ iff \ A \stackrel{<}{_>} 0. \tag{15}$$

A higher tariff can result in a lower domestic (tariff-inclusive) price of the importable good, *i.e.*, $\hat{P}/\hat{T} < 0$. This is the well-known Metzler paradox ⟨see Metzler [1949]⟩. A necessary and sufficient condition for that is $[A/(a+a^*-1)] > 1$, or by using the definitions of A and a,

$$a^* + \left[m/\alpha T\right] / \left[1 - (mt/\alpha T)\right] < 1. \tag{16}$$

If initially there is a free trade, then $t = 0$ and (16) reduces to

$$a^* + m/\alpha < 1. \tag{17}$$

It is well known ⟨see, for example, Caves, Frankel and Jones [1993] p. 657⟩ that, in the case of barter trade, a necessary and sufficient condition to rule out the Metzler paradox is the condition $a^* + m > 1$, also known as the Metzler condition. Moreover, the same result holds in the monetary model of Anderson and Takayama ⟨[1978] and [1981]⟩. In our framework, however, since α can be greater or less than one, depending on whether ϕ_1 is greater or less than ϕ_2, this result is in need of a revision. In particular, the Metzler condition is necessary and sufficient to rule out the paradox if and only if $\phi_1 = \phi_2$. In the more likely case, however, where $\phi_1 \neq \phi_2$, and hence $\alpha \neq 1$, this result does not hold. More specifically, if $\phi_1 > \phi_2$, or $\alpha > 1$, then the Metzler condition is only necessary to rule the Metzler paradox. If, on the other hand, $\phi_1 < \phi_2$, or $\alpha < 1$, then the same condition becomes sufficient. We summarize our findings as follows:

Proposition 1: *If $\phi_1 \neq \phi_2$ then the Metzler condition is not both necessary and sufficient to rule out the Metzler paradox. If $\phi_1 > \phi_2$ it is necessary while if $\phi_1 < \phi_2$ it is sufficient.*

V. The Optimum Tariff

In barter trade models, the terms of trade move in favor of the tariff-imposing country if the latter is large enough to influence the world prices. This tends to increase national welfare due to the exploitation of a country's monopoly power in the world market. At the same time, however, a tariff impairs productive efficiency and tends to lower welfare. It follows that there exists a unique tariff rate, known as the optimum tariff, at which national welfare is maximized. This optimum tariff is given by $1/(a^* - 1)$ so that a necessary and sufficient condition for the optimum tariff to be positive is that there exists a range of the foreign offer curve where $a^* > 1$. In this section we derive an analogous formula for the optimum tariff for our monetary economy.

First rewrite equation (12) as

$$\hat{T} = -\frac{a + a^* - 1}{A}\hat{p} + \frac{\hat{A}}{A}\hat{T}^*. \tag{18}$$

Substituting (18) into (10) and making use of some algebraic manipulations, which can be found in the Appendix, we obtain

$$dY = \frac{E_1^*}{\alpha}\left\{ -(1+\gamma)T + \frac{a + a^* - 1}{A}\gamma T + (T-1)a^* \right\}\hat{p}$$

$$-\frac{E_1^*}{\alpha}\left\{ \frac{A^*}{A}\gamma T + (T-1)A^* \right\}\hat{T}^*. \tag{19}$$

where $\gamma \equiv [(\phi_2 - \phi_1)/(1+\phi_1)]e$. Assuming a given foreign tariff ($\hat{T}^* = 0$), the condition for the home country's optimum tariff is derived by setting dY in (19) equal to zero. In fact, as we show in the Appendix

$$t_{opt} = \frac{1}{a^* - 1} - \left(1 + \frac{1}{a^* - 1}\right)\frac{(\phi_2 - \phi_1)e}{(1+\phi_1)s + (1+\phi_2)e}. \tag{20}$$

If $\phi_1 = \phi_2$, with the barter economy being a special case, (20) reduces to the standard formula for the optimum tariff. In the case of non-uniform monetization, the optimal tariff becomes higher (lower) if $\phi_1 > (<) \phi_2$. In fact, if $\phi_1 < \phi_2$ the optimal tariff may be negative even in the elastic range of the foreign offer curve. The explanation to this modified formula is quite intuitive. For instance, if money is more efficacious in the importable sector so that

$\phi_1 > \phi_2$, then our discussion in section 3 implies that a decrease in the consumption of the importables (D_2) is welfare improving since it reduces the gap between the *MRS* and the domestic price ratio. In this case, an increase in the tariff rate serves the purpose of reducing D_2 which leads to a higher optimal tariff the standard barter one. We summarize our finding in the following proposition.

Proposition 2: *In the case of non-uniform monetization, the optimal tariff becomes higher (lower) than the one in standard barter models if* $\phi_1 > (<) \phi_2$.

As a final remark, in the case of a small home country where $a^* = \infty$, equation (20) becomes

$$t_{opt} = \frac{(\phi_2 - \phi_1)e}{(1 + \phi_1)s + (1 + \phi_2)e}.$$

Thus, contrary to standard results, a free trade policy is not optimal for a small country, unless either $\phi_1 = \phi_2$, or $e = 0$, or $s = \infty$.[9]

VI. Conclusions

In this paper, we have examined the effects of a tariff on the terms of trade and the domestic-price ratio in a large country model with monetary distortions generated by a modified cash-in-advance constraint. It is shown that the presence of the monetary distortion creates a divergence between the marginal rate of substitution and the domestic price ratio. This then leads to a number of novel results contrary to those obtained in barter trade models. For instance, it is possible for an increase in the domestic tariff to worsen the domestic terms of trade if the importable sector is severely distorted by the cash-in-advance constraint. We also examine the relationship between the Metzler condition and the Metzler paradox. Finally, after deriving the optimum tariff formula for our monetary economy, we found that the conventional formula derived in barter trade models has a downward (upward) bias if money is more (less) efficacious in the importable sector.

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9. See Palivos and Yip [1997] for further details for the small country case.

To conclude the paper, notice that our way of introducing money into the world economy via a cash-in-advance constraint models money as a demand-side distortion. Hence, the presence of money in our model creates a divergence between the *MRS* and the domestic-price ratio. There has been a considerable number of studies in the literature which model money as a factor of production – the so called "money-in-the-production" approach ⟨*e.g.*, Wang and Yip [1992]⟩. If we adopt such an approach to introduce money into the world economy, then money creates a supply-side distortion and so we conjecture that it will create a divergence between the marginal rate of transformation (*MRT*) and the domestic-price ratio. This may provide further insights into the role of money in international trade issues and we intend to tackle this in future work.

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Appendix

1. Derivation of (10).

Differentiating (6) one obtains

$$dD_1 + PdD_2 + D_2dP = dX_1 + PdX_2 + X_2dP + (T-1)E_2dp$$
$$+ pE_2dT + (T-1)pdE_2,$$

or, by using $dX_1 + PdX_2 = 0$, $E_2 \equiv D_2 - X_2$ and $dY = dD_1 + PdD_2 + [(\phi_2 - \phi_1)/(1+\phi_1)]PdD_2$,

$$dY = -E_2dP + (T-1)pdE_2 + (T-1)E_2dp + pE_2dT + \frac{\phi_2 - \phi_1}{1+\phi_1}PdD_2 \quad (A1)$$

Furthermore, $P = pT$ and hence $dP = Tdp + pdT$. Substituting this in (A1) yields (10).

2. Derivation of (11).

Differentiation of $P = pT$ yields $\hat{P} = \hat{p} + \hat{T}$. Substituting this and (10) into (9) yields

$$[1 - (mt/T)]\hat{E}_2$$
$$= -[e+s+(m/T)]\hat{p} - (e+s)\hat{T} + [(\phi_2 - \phi_1)/(1+\phi_1)](m/E_2)dD_2. \quad (A2)$$

Furthermore, differentiating $D_2 = D_2(P, Y)$ one obtains

$$\alpha dD_2 = E_2\{-[e+(m/T)]\hat{p} - e\hat{T} + (mt/T)\hat{E}_2\}, \qquad (A3)$$

where $\alpha \equiv 1 - [m(\phi_2 - \phi_1)/(1 + \phi_1)] > 0$. Substitution of (A3) into (A2) results in (11).

3. Derivation of (19).

Differentiating the balance of payments condition, $pE_2 = E_1^*$ and $D_2 = D_2$ (P, Y), one obtains after some simple manipulations $pdE_2 = dE_1^* - E_2dp$ and $dD_2 = -E_2e(\hat{p} + \hat{T}) + (m/P)dY$, respectively. Substitution of the last two expressions in (10) yields

$$dY = (E_1^*/\alpha)[-\hat{T}p + (T-1)\hat{E}_1^* - \gamma T(\hat{p} + \hat{T})],$$

where $\gamma \equiv [(\phi_2 - \phi_1)/(1+\phi_1)]e$, or upon making use of (12) and $\hat{E}_1^* = -a^*\hat{p} - \hat{A}^*\hat{T}^*$ [the analogue of (4) for the foreign country] (19).

4. Derivation of (20).

Setting $\hat{T}^* = dY = 0$ and using the equations $A = \mu\{s + e\alpha^{-1}\}$, $a = \mu\{s + [e + (m/T)]\alpha^{-1}\}$, and the definitions of μ and T, we obtain

$$T_{opt} = \frac{a^*}{a^* - 1} \frac{s\alpha + e - m\gamma}{s\alpha + e - m\gamma + \gamma\alpha} \,,$$

or, since $e - \gamma m = e\alpha$ and $a^*/(a^* - 1) = 1 + 1/(a^* - 1)$,

$$T_{opt} = \left(1 + \frac{1}{a^* - 1}\right)\frac{s + e}{s + e + \gamma} = 1 + \frac{1}{a^* - 1} - \left(1 + \frac{1}{a^* - 1}\right)\frac{\gamma}{s + e + \gamma} \,.$$

Thus,

$$t_{opt} = T_{opt} - 1 = \frac{1}{a^* - 1} - \left(1 + \frac{1}{a^* - 1}\right)\frac{\gamma}{s + e + \gamma} \,,$$

which, upon substitution of $\gamma \equiv [(\phi_2 - \phi_1)/(1+\phi_1)]e$, yields (20).