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FISHERIAN AND RICARDIAN TRADE

by

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Abstract

Fisherian and Ricardian Trade

by

Stefan Sinn

This paper discusses the difference between Fisherian and Ricardian trade in terms of a simple two-period model of a small open economy. Fisherian or intertemporal trade occurs when goods are traded today against the promise to deliver goods in the future. The resulting net resource transfer is equal to an international flow of capital. Ricardian trade occurs when there are no international capital flows and the trade account is balanced. The model suggests that once international trade is primarily of Fisherian nature, the direction and volume of trade are best explained by variables that take intertemporal aspects into consideration such as the interest rate and the expected prices of goods.

JEL Classification: F21, F32, F41

Key words: International capital mobility; saving; investment; current account adjustment.

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Fisherian and Ricardian Trade*

by

Stefan Sinn

1. Introduction

Modern open-economy macroeconomics is based upon individual utility maximisation within an intertemporal framework (Blanchard, Fischer (1989); Krugman, Obstfeld (1991), Frenkel, Razin (1987)). The basic idea is an old one which goes back to the work of Irving Fisher (1930): households maximize their utility over time. This leads to a smooth intertemporal pattern of consumption which is achieved by borrowing or lending capital. Assuming that all households living in a country can be aggregated to a representative household, the Fisherian idea can be applied to whole economies. In this case the model furnishes an explanation of movements in the current account balance, which is equal to aggregate saving minus aggregate investment.¹

In the present paper I develop a prototype model along these lines designed to stress the difference between static and intertemporal trade. Static international trade occurs when the trade account is balanced. In this Ricardian set-up no net

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¹ Analyses in the vein of this paper were first suggested by Baldwin (1966), Miller (1968), and Webb (1970) who extended the original Fisherian set-up with one consumption good to include capital goods. More recent treatments are by Svensson (1984), Niehans (1984), and the empirical studies by Sachs (1981, 1982).

flows of real capital take place between countries.² Inter-temporal trade on the other hand involves an exchange of goods today against the promise to deliver goods in the future. At any point in time, the trade account is not balanced and the country's net external asset position increases (trade surplus) or falls (deficit on the trade account). I shall refer to this type of trade as Fisherian international trade.³

The crucial features of the model developed in sections 2. to 4. may be summarized as follows. First of all, it starts from "first principles" by assuming individual utility maximization and consistent budget constraints over the time horizon of the model. Secondly, the structure chosen is as simple as possible. All markets are assumed to clear and the country is small enough to take world prices as given. The time horizon of the model is two periods. There are two goods, a final consumption good and an intermediate good that is used to enhance future consumption. The model thus is able to take into account aspects of time which would not be the case if output consisted of final consumption goods only. Third, the model emphasises the role of prices and their effects on individual decisions. More precisely, it argues that essentially five prices determine saving, investment, and the current account balance of a small open economy: the current and the expected price of consumption goods, the current and the expected price of investment goods, and the real interest rate. Finally, the model is real in the sense that purely monetary changes such as variations in the monetary base are assumed not to matter for the results.

The distinction between Ricardian and Fisherian international trade has important empirical implications. As long as trade is

² Note that the term Ricardian is a catch-all expression for the classical school of international trade theory.

³ Sinn (1990) discusses the importance of intertemporal trade for the determination of a country's net external asset position.

essentially Ricardian in nature, the traditional roles of relative world prices and productivity differentials are crucial for explaining the composition and volume of international trade. If, however, Fisherian international trade assumes importance, the real rate of interest and the expected prices of the traded goods begin to matter in explaining international patterns of trade. I believe the evidence of ever larger current account balances throughout the 1980s is sufficient to underline the growing importance of Fisherian trade. In the final section I elaborate on some areas of research where the distinction of Ricardian and Fisherian trade might prove useful.

2. Equilibrium for the small open economy: A graphical exposition

Consider the following model of a small open economy. The analysis is confined to two periods. In period 1 two goods are produced, one used for consumption ("wine"), another as an input for production ("machines").⁴ In the second period, the additional income from investment in the first period becomes available. In the second period only consumption goods are produced. The capital equipment installed in the first period is sold on the world market at the end of the second period. Households can borrow and lend freely on the international capital market. Firms maximise profit and households maximise utility. As a first step, the intertemporal decision calculus for the whole economy is sketched out in Figure 1.

The supply side of this model economy is determined by the decisions of individual firms. Profit-maximising firms will equate the marginal product of capital to the world interest rate. The optimal level of investment (point A) is found by

⁴ The appendix contains the algebra of this model.

shifting the capital market line to its highest point of tangency with the intertemporal production possibility frontier, DAC. The capital market line is the locus of all possible combinations of present consumption and future consumption. This is only the case if, as I assume, international capital mobility prevails. In that case the capital market line coincides with the country's intertemporal consumption possibility frontier (henceforth ICPF). In all other cases, a country's ICPF does not coincide with the capital market line (see section 3). In the appendix it is shown that the optimality condition at point A is

$$[1] \quad p_c^e h_I = \theta_1 [r - \hat{p}_i^e]$$

The expression on the left hand side of equation [1] denotes the expected marginal value product of capital invested in period 1 which is the product of the expected price of the consumption good expected to prevail in period 2, p_c^e and the physical marginal product of capital, h_I .⁵ The cost of capital is captured by the right hand side of equation [1], it consists of the relative price of investment and consumption goods in period 1, θ_1 , multiplied by the real interest rate r minus the expected change in the price of the capital good, \hat{p}_i^e . The intuition behind the last term is straightforward: an expected increase in the market price of the capital good will lower the cost of capital of the investment project.

Equation [1] can be rewritten to yield

$$[1'] \quad p_c^e h_I = \theta_1 [1+r] - p_i^e$$

⁵ All variables are deflated by the current price of the consumer good p_c^1 which is set at unity. This implies that the household evaluates all magnitudes in period 1 consumption good prices.

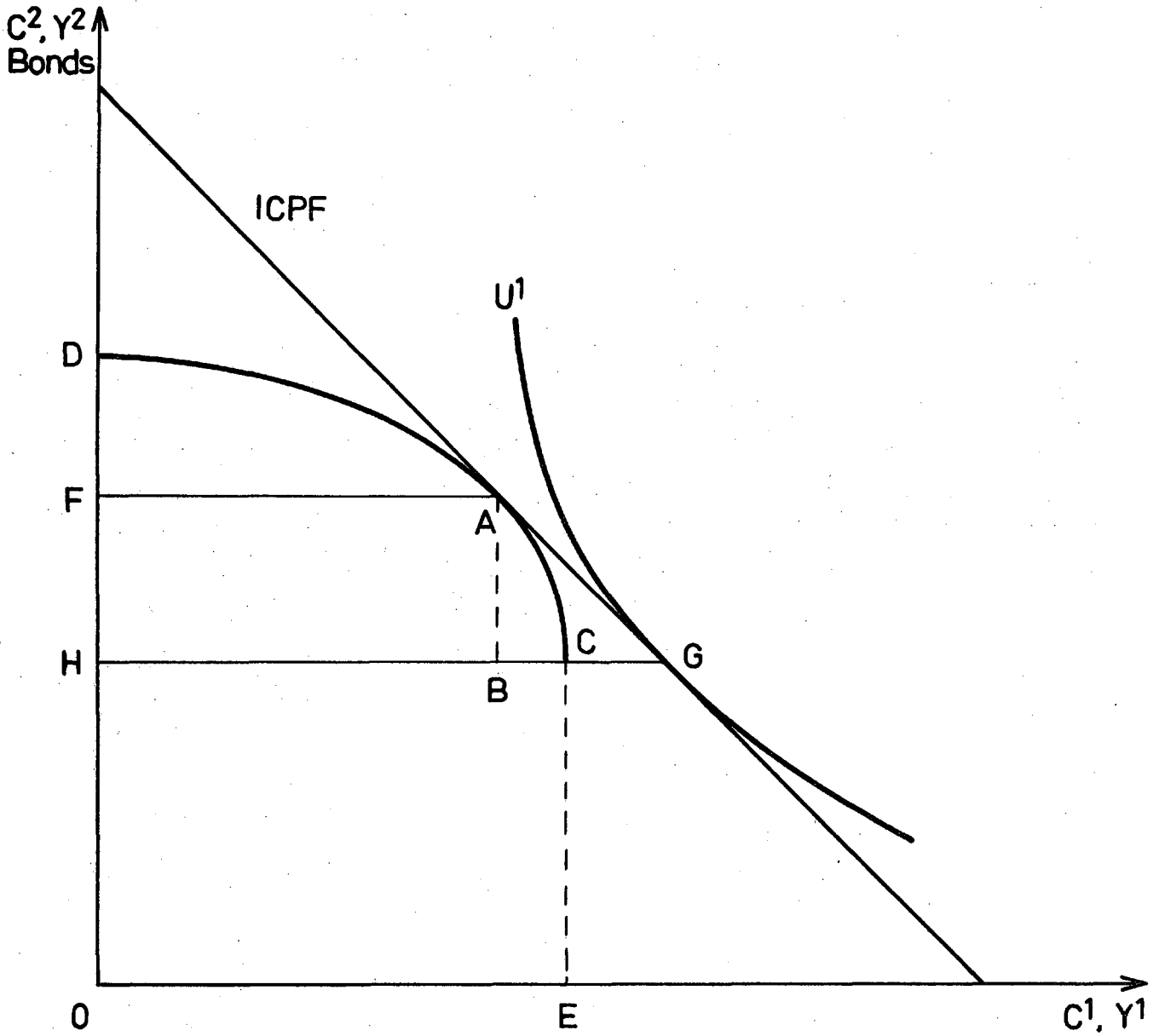
Equation [1'] implies a q-theoretic interpretation of investment: investment ceases once the difference between the current replacement cost of machines and their expected market value equals the expected marginal value product. The level of investment will be larger the smaller the gap between current replacement cost and their expected market value.⁶ In empirical applications of the model p_i^e can be associated with the currently prevailing stock exchange index while θ_1 is the relation between the deflators of investment and consumption.

The optimal level of investment BC can be read off to the left of E. OE represents the initial level of income which is a function of the existing capital stock \bar{K} inherited from the past and the exogenous labour supply \bar{L} . Note that if no investment occurs in period 1, period 2 income will be OH which is assumed be lower than OE because of the physical depreciation of the initial capital stock. The shape of the intertemporal production possibility frontier describes the productivity of domestic investment: A steeper slope implies a higher marginal productivity of investment. Output produced in period 2 will be OF, where HF minus BC represents the total return on investment undertaken in period 1.

The demand side of the model is governed by utility-maximising consumers. The problem of the consumer is to choose consumption levels in both periods given initial income OE, the ICPF, his time preference incorporated in the indifference curve U^1 and the world interest rate r . The optimal level of consumption in period 1, GH, is found at the point of tangency G of the ICPF with the utility indifference curve U^1 . Equation [2] expresses the optimality condition which must be fulfilled at G as

⁶ Niehans (1984) derives a similar relationship in a different model.

Figure 1 - Fisherian Trade



$$[2] \quad U_C(1) [U_C(2)]^{-1} = \beta [p_C^e]^{\alpha}^{-1}$$

This is the familiar condition for intertemporal consumption optimality which states that the marginal rate of substitution between present and future consumption is equal to the ratio of

the subjective discount factor β to the market discount factor α times the relative price of future and current consumption goods (remember that p_c^1 has been set to unity).⁷

Supply and demand side together determine the balance of payments. As one possibility, consider the scenario of Figure 1. While points A and G have to coincide in an economy closed to international capital movements, the existence of international borrowing and lending allows the country to absorb more than it produces. In period 1 domestic investment BC exceeds national (dis)saving CG by the amount BG, this difference is equal to the trade deficit. Since there are no transactions on the service account of the balance of payments in the first period, the trade deficit equals the current account deficit. The model is confined to two periods, debt plus interest must therefore be repaid and transferred abroad in the second period. This transfer of real resources is equal to FH, the current account surplus in the second period. Note that the trade account surplus in the second period (not shown in Figure 1) must exceed the current account surplus by the amount of interest payments to foreign lenders. Bonds can easily be introduced in the Fisherian framework. In my example, residents sell to nonresidents pieces of paper promising the share AB of their future income against immediate access to foreign real resources used partly for investment (BC) and partly for consumption (CG). Such pieces of paper are commonly known as bonds. In analogy to static trade theory, ABG might be called the intertemporal trade triangle.

Up to now I only consider Fisherian and not Ricardian trade among nations. It is possible to incorporate Ricardian international trade in the first period into the model by adding the

⁷ Note that the partial derivative of the utility function with respect to consumption, evaluated at the period 1 values of the explanatory variables of the utility function, is given by the symbol $U_c(1)$.

production possibility frontier HBE for producing consumption and investment goods in the fourth quadrant of a cartesian cross which has the original Fisherian diagram in its first quadrant (Figure 2).⁸ In the fourth quadrant the terms of trade for trading investment and consumption goods are indicated by the slope of the line GBE'. In the third quadrant the relation between investment in period 1 and output in period 2 from the first quadrant is redrawn.

Optimality in the production of the two goods occurs at the point of tangency of the terms of trade line with the production possibility frontier. At this point B the optimality condition

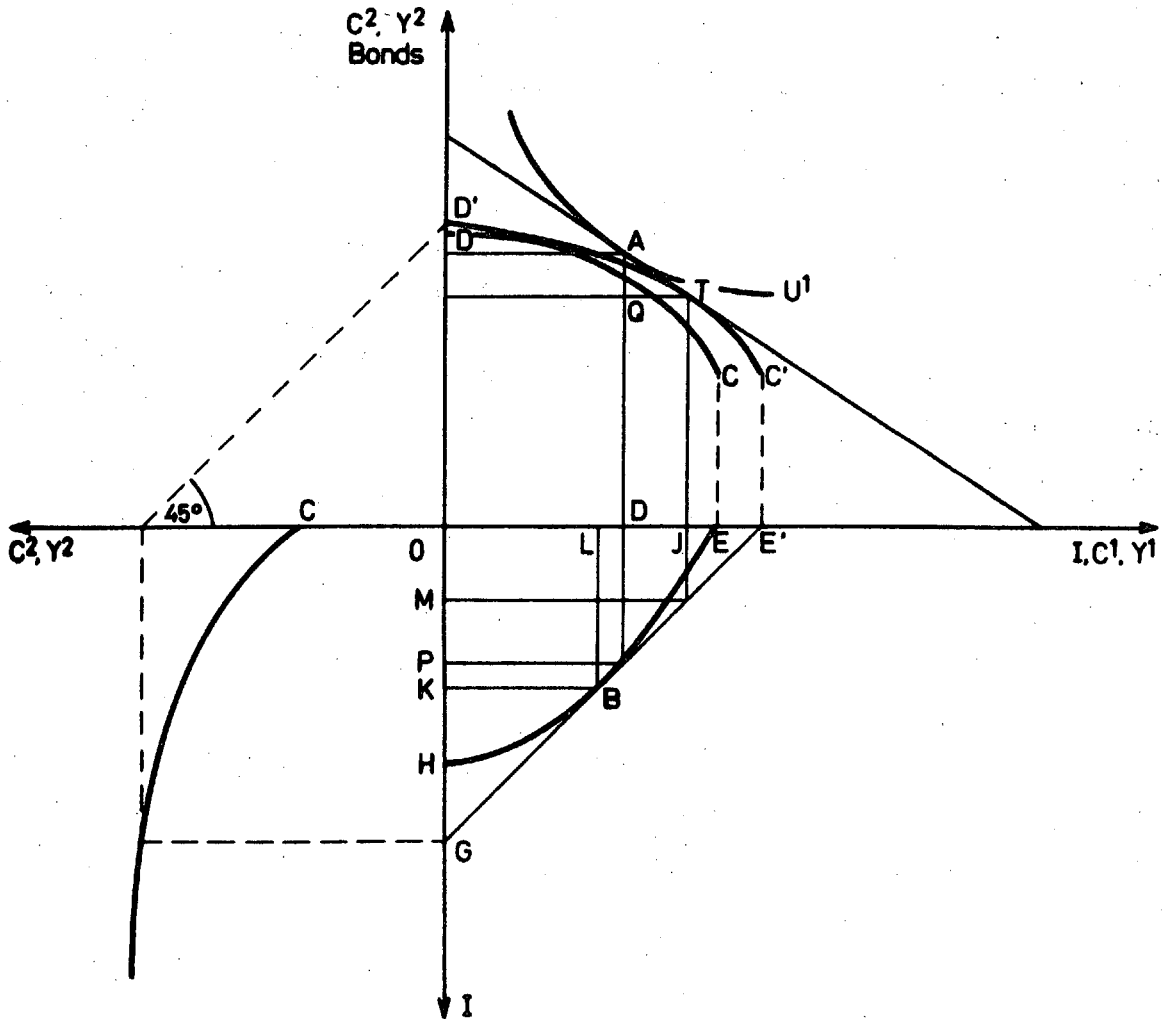
$$[3] \quad Q_c = -[\theta_1]^{-1}$$

holds which states that the marginal rate of product transformation in period 1, Q_c , is equal to the terms of trade. Equation [3] may also be expressed as the condition that the loss in revenue from producing and selling fewer machines due to an expansion of consumption good production by one unit ($-p_i^1 Q_c$) is equal to the revenue gained from selling that additional consumption good (p_c^1). With this apparatus at hand, it is possible to give a precise meaning to the current account balance of a country firmly founded in an intertemporal general equilibrium framework.

Consider points A, B, and T in Figure 2. Point A is the point of tangency of the international capital market line with the intertemporal utility indifference curve U^1 . Point A indicates the representative household's optimal decision on consumption and saving: out of total current income (OE') OD are consumed and DE' are saved. Point B indicates the optimal production of

⁸ This approach is due to Baldwin (1966).

Figure 2 - Fisherian and Ricardian Trade



consumption and investment goods given the terms of trade line GBE' and the production possibility frontier HBE . The country produces OK investment goods and OL consumption goods. Point T indicates the optimal deployment of investment goods within the economy. The optimal level of investment is OM (JE' in terms of consumption goods). Points A, B , and T represent decisions that can be undertaken independently of each other as long as the economy is open to movements of capital and goods: Saving need not coincide with investment (points A and T) and the deploy-

ment of investment goods need not coincide with the production of investment goods (points B and T). Finally the amount of consumption goods produced need not equal the domestic absorption of consumption goods (points A and B). Notice that the three optimality decisions are a function of the exogenous variables facing the economy, namely the interest rate, the two goods prices as well as their expected values, and the subjective discount factor. All three decisions taken together determine the current account balance. The economy trades LD consumption goods (import) against PK investment goods (export) to obtain the optimal amount of consumption goods. Furthermore, additional investment goods MP are exported and traded against the foreign promise to deliver AQ consumption goods in period 2, i.e. against bonds of that magnitude. This last trade leads to a current account surplus DJ in period 1 which is equivalent to a capital export of similar magnitude.

3. Increasing international openness

With the model presented, it is a straightforward exercise to give a precise meaning to the notion of increasing international openness which I interpret as the move from autarky to Ricardian trade and then to Fisherian trade. Consider first the extreme example of an autarkic country, the Robinson Crusoe economy. Robinson Crusoe's decisions on the sectoral composition of output (point B), on the deployment of capital (point T), and on the consumption and saving choice (point A) are all interdependent. Assume that his current income consists of a harvest of grain. Then the amount of grain he saves and does not consume is necessarily equal to the amount he invests by planting it into the soil. In addition, it is trivially true that the amount of grain planted (eaten) is equal to the amount of grain produced for investment (consumption) purposes. The ICPF of this autarkic economy is DCE.

The first step towards complete openness moves the economy from autarky to Ricardian trade. The economy exchanges goods with other economies but is closed to international capital movements. In terms of Figure 2, points A and T coincide so that saving equals investment. In the appendix it is shown that the optimality condition in that case is

$$[4] \quad p_{cI}^e h_I = \theta_1 [U_C(1) p_C^e [U_C(2)\beta]^{-1} - 1 - \hat{p}_1^e]$$

In contrast to a world of complete capital mobility (cf. equation [1]), equation [4] implies that the level of investment depends on the marginal rate of substitution between current and future consumption. An increase in planned investment requires an increase in saving in order to be realized. Other things equal, the "impatient" country which places a high value on current consumption and therefore saves little chooses a lower level of investment. The production decision, however, may be taken independently of domestic demand for the two goods. World market conditions, as given by the terms of trade θ_1 , determine the optimal production pattern. Empirically, the trade volume (export and import) is large relative to the trade account balance, which tends towards zero. In terms of the Robinson Crusoe economy, one can observe trade between the islands. However, no foreign investment occurs: Robinson Crusoe does not take advantage of more fertile soil on other islands for planting his grain seeds. Thus whenever goods leave his island, a shipment of equal value is observed to enter the harbour.

Opening up the economy to Ricardian trade changes the consumption possibilities of the economy and the relative price of goods that it faces. Note first of all that intertemporal consumption possibilities are enlarged relative to autarky. The new ICPF can be constructed as follows. At point B of Figure 2 the economy produces OK investment goods and OL consumption goods. The maximum consumption in period 1 is achieved by selling all investment goods on the world market. Given the

terms of trade line GBE' , the economy may import at most LE' consumption goods. This establishes E' as the bottom right point of the extended (relative to autarky) ICPF. The top left point D' can be constructed by assuming that the economy exchanges all the consumption goods OL that it produces for KG investment goods on the world market. Using quadrants two and three, it can be shown that by deploying a total amount of OG investment goods in the first period the economy produces a total income in period 2 of OD' . The extended ICPF is therefore given by $D'C'E'$. Note that the difference in the areas covered by the autarkic ICPF (DCE) and the open-to-trade ICPF ($D'C'E'$) is a measure of the gains from international trade. In quadrant 4 these gains are depicted as the two areas between the production possibility frontier and the terms of trade line. The second effect of opening the economy is to change the relative price of consumption and investment goods. Pre-trade prices are governed by domestic supply and demand conditions. After the introduction of unhindered trade the relative price is governed by global supply and demand conditions. This may well imply a large shift of the relative price relevant for the decisions of the domestic agents.

The economy is truly open once international capital movements occur. In this case all three decisions - how much to invest, what to produce, and how much to consume now - are independent of each other. Empirically, one can observe increasing trade and current account balances. For Robinson Crusoe this opens up a range of new activities. He may now send grain seeds to another island with more fertile soil than his own. An agent on that island, call him Friday, in turn issues a bond promising Robinson Crusoe a share of next year's harvest from this year's grain export. Thus the only visible return Robinson Crusoe gets today in return for having sent his goods abroad is a piece of paper by Friday promising future shipments of goods.

Opening the economy to capital movements has implications for the locus of the economy's consumption possibilities and the

interest rate that it faces. First, allowing international capital movements further extends the consumption possibilities of the representative household (Webb (1970)). The capital market line tangent to the intertemporal production possibility frontier at T is the ICPF with free capital movements. The gains in welfare from permitting international capital movements can be measured by the areas between the open-to-trade ICPF (D'C'E') and the capital market line. Secondly, the liberalization of international capital movements leads to a change in the real interest rate for the small open economy. If there is a positive differential between the domestic and the international real interest rate before liberalization, liberalization is expected to lead to a fall in the domestic real interest rate. In that case capital inflows from abroad are prevented by controlling capital flows. The prevention of capital outflows is perhaps the more widespread use of capital controls. In that case a negative interest rate differential between the local interest rate and the world interest rate prevails before liberalization and the freeing of capital flows leads to an increase in the real interest rate.

4. External shocks: Effects on the small open economy

The discussion of my model would be incomplete without an analysis of how its major aggregates react to changes in exogenous world market variables. The previous section underlines the need for such an exercise in comparative statics because it associates changes in international openness with changes in relative goods prices and interest rates. The effects of these price changes on the main aggregates of my model are calculated in the appendix. More precisely, the following sequence of events is analysed: at the beginning of period 1, the representative household plans production, consumption in both periods and investment in the first period given the known period 1 values and the expected period 2 values of the exogenous variables. Shortly after in period 1, the shock occurs changing

any one of the exogenous variables. The household revises its original plans and a new set of values for the endogenous variables is realized. Table 1 summarizes the sign of the effects of various external shocks on the main dependent variables.

Table 1 - Effects of External Shocks on the Small Open Economy

	Effect on				
	Invest- ment	Consumption Period 1	Current Account Deficit Period 1	Production of Consump- tion Goods	Wealth
Increase in the:					
Relative price of the investment good and the con- sumption good (θ_1)	(-)	(+/-) ¹	(-) ⁴	(-)	(+/-) ⁵
World interest rate (r)	(-)	(-) ²	(-) ²	(0)	(+/-) ⁶
Expected price of the consumption good (p_c^e)	(+)	(+) ³	(+) ³	(0)	(+/-) ⁷
Expected price of the in- vestment good (p_i^e)	(+)	(+)	(+)	(0)	(+)

1. If the country is a net exporter of machines ($I^* < Q^*$), consumption increases. If it is a net importer ($I^* > Q^*$), consumption falls.
2. If the country has a current account deficit in the first period. If it has a current account surplus, the effect is ambiguous.

3. Assuming that second period production exceeds second period consumption, i.e. $C_2^* < f(\bar{K}, \bar{L}) + h(I^*)$. Otherwise the effect is ambiguous.
4. If the country is a net exporter of machines ($I^* < Q^*$) the deficit falls. If the country is a net importer of machines, the sign is ambiguous.
5. If the country is a net exporter of machines ($Q^* > I^*$), wealth increases. Otherwise the effect on wealth is negative.
6. If the country has a current account deficit in the first period, wealth declines. Otherwise the effect on wealth is positive.
7. If second period production exceeds second period consumption ($C_2^* < f(\bar{K}, \bar{L}) + h(I^*)$), wealth increases. If second period consumption exceeds second period production, wealth falls.

The results of Table 1 can be summarized as follows:

- The effects on investment can be interpreted as effects on the level of future income. An increase in the current relative price of the investment good leads to a fall in investment and therefore to a lower level of future income. Essentially, the small open economy devotes less resources to capital accumulation because the current opportunity cost of these resources in terms of units of consumption foregone has increased. Not surprisingly, an increase in the real interest rate has the same effect of depressing the future level of income. Finally, both a rise in the expected price of the consumption good and a rise in the expected price of the investment good increase investment. In the first case the expected marginal value product of investment increases which leads to an increase in the range of profitable investment plans. In the second case, the cost of capital falls because \hat{p}_1^e rises (see equation [1]). This also has the effect of increasing the range of profitable investment plans.

- The only external variable that matters for the decision on the composition of output in the first period is the relative price of the two goods. If investment goods become more expensive relative to consumption goods, the production of consumption goods falls.

- The impact of changes in the exogenous variables on consumption in the first period depends on both the wealth effect and

the intertemporal substitution effect.⁹ Since the household derives utility from consumption only, a change in wealth implies a change in the consumption possibilities. Intertemporal substitution effects occur when the price of consumption today changes relative to the price of consumption tomorrow.

A change in θ_1 , the current relative price of the investment good, leads to a change in wealth only since it does not affect the relative price of current and future consumption. The direction of the wealth effect depends on whether in the first period more machines are installed in the country than produced, i.e. whether the country is a net importer of machines or not. Since a rise in the relative price of the investment good benefits producers but hurts investors, the country's wealth increases as a result of the rise in θ_1 if it is a net exporter of machines. As a consequence, in that case consumption also rises.

A rise in the interest rate produces two effects: first of all, it makes present consumption more expensive relative to future consumption (intertemporal substitution effect). By itself, this would suggest a fall in current consumption. Secondly, the country's wealth increases or falls depending on whether it lends or borrows on net in the first period. If it is a net lender, its consumption should increase, leading to an ambiguous overall effect. If it is a net borrower, present consumption should fall leading to a negative overall effect.

A similar reasoning can be applied to the analysis of a rise in the future price of the consumption good. On the one hand it makes future consumption more expensive relative to current consumption thereby increasing current consumption. On the

⁹ Note that by wealth I mean the sum of the discounted utility streams from consumption in period 1 and period 2 and not a stock of assets held at the beginning of the planning period.

other hand it leads to an increase (decrease) in wealth if the country is a net exporter (importer) of consumption goods in the second period.¹⁰ Therefore, the effect is unambiguously positive only if the country is a net exporter of consumption goods in the second period. Otherwise the effect is ambiguous because intertemporal substitution effect and wealth effect work into different directions.

Finally, the effect of a rise in the future price of the investment good is a pure wealth effect. A rise in the expected price of the machine will increase the consumption possibilities in the second period because it increases the real value of the machine (in terms of consumption goods prices) which is being sold off at the end of period 2, the end of the planning horizon. Since international capital markets allow the economy to consume some of that expected rise in second period income in advance and since the household desires to smooth its consumption profile over time, consumption in period 1 will rise as a result of the rise in p_1^e .

- The effects on the current account deficit can be seen as the difference between the effect on saving and the effect on investment. In addition, if θ_1 changes there is a static terms of trade effect which leads to a revaluation of the existing trade account balance. Thus a rise in θ_1 will increase (decrease) planned saving if the country is a net importer (exporter) of machines. At the same it will depress investment. In addition, the rise in θ_1 leads to a revaluation of current net exports. This "windfall" profit increases the wealth of net exporters of machines and lowers the wealth of net importers. Somewhat surprisingly, the net result of all three effects is unambiguously negative (the current account deficit decreases) in the case of

¹⁰ Since the consumption good is the only good produced in the second period, this condition is equivalent to the condition that the country's second period production exceeds (is less than) its absorption.

the net exporter of machines although the fall in saving induced by θ_1 's rise tends to work in the other direction. For the net importer the effect is ambiguous. Although both the induced increase in saving and the fall in investment tend to reduce the deficit, the static terms of trade effect working in the opposite direction renders the overall effect ambiguous. Note that this result is contrary to the perceived wisdom regarding the effect of terms of trade changes on the current account: an increase of the relative price of a good that a country exports on net leads to a lower current account deficit. The rationale of this result rests with the assumption of the small open economy: if a country takes world market prices as given, the terms of trade rise increases its wealth. Applying a similar reasoning to shocks from the other external variables produces the results reported in Table 1. A particular interesting result concerns the effect of interest rate changes. A country with a current account deficit experiences a reduction of that deficit while the effect on a net lender's current account surplus is ambiguous. This result provides a resolution to Tarshis' paradox that not all small economies can respond to a rise in the world interest rate by exporting more capital (Tarshis (1972)). The point is that whether or not a country increases net exports depends on initial conditions.

5. Conclusions

What has been learned from distinguishing Ricardian from Fisherian trade? I think the most important lessons can be summarized in the following five hints.

Hint No. 1

The nature of the current account balance is essentially intertemporal. This implies that international trade can be explained by factors that are of an intertemporal nature, i.e.

changes in the interest rate and changes of expected relative prices.

Hint No. 2

The analysis implies that the current account balance is a residual that is determined by saving and investment decisions. It follows that any variable thought to be able to affect the current account must do so by moving saving and/or investment.

Hint No. 3

International capital flows are essentially a real phenomenon that is intimately related to international trade. The current account surplus is the correct measure for the transfer of real resources from the lending country to the borrowing country, i.e. the new investment of the lender in the debtor country. In turn, a debtor country can only repay its debt if it transfers real resources to the lender. Financial capital mobility or portfolio arbitrage involves the trade of financial assets, i.e. claims on existing capital. While an interesting phenomenon on its own, financial capital mobility has no direct implications for economic welfare.¹¹

Hint No. 4

International capital flows are commonly thought to have their cause in differences in the real rate of return. As a corollary, flows are expected to cease once they have brought about equality in rates of return. In the present model I assume that

¹¹ Sinn (1991) argues that the appropriate measure for the extent of financial capital mobility are interest rate parity tests while the extent of real capital mobility is best measured by correlating saving and investment. Both tests measure different phenomena. This point is also made by Leachman (1991).

equality of the real rates of return prevails all the time; however, there remains plenty of scope for international capital flows if consumers try to smooth consumption. In particular, the model shows that international capital flows in order to cushion the impact of common global shocks that have differential impacts on countries depending on their initial position. Whether capital flows primarily for this reason or in order to equalize rates of return is an empirical question that I intend to pursue in future research.

Hint No. 5

Capital goods prices matter.¹² More precisely, a high relative price of machines depresses investment. Note, however, that a high relative price for machines is not necessarily bad news for a country. The wealth of a country is only negatively affected if it imports machines on net. This casts some doubt on the finding of De Long and Summers (1991) that there is a strong negative association between capital goods prices and economic growth.

¹² This point is emphasised by Niehans (1984).

Appendix

Consider the following algebraic version of the model presented. The representative household derives utility from consumption in period 1, C_1 , and consumption in period 2, C_2 . The planning period consists of two periods. In the first period the representative household invests in production facilities in order to augment consumption in the second period. First period investment, I , increases second period output by the amount $h(I)$. Output in period 2 can only be consumed or transferred abroad. The machines installed in the first period are sold at the end of period 2 at expected price p_i^e . In the first period the household produces the quantity c of the consumption good and the quantity i of the investment good using the production function $f(\bar{K}, \bar{L})$ where \bar{K} is the capital stock of the economy in the first period determined by past investment and \bar{L} is exogenous work effort in the first period. In the second period, it is assumed that the economy produces the consumption good only which it can sell at expected price p_c^e . Total output in the second period is the sum of the output attributable to past investment and labour, $f(\bar{K}, \bar{L})$ and of the output attributable to investment $h(I)$. In other words, $h(I)$ is the total real return to investment. The economy faces given first period world market prices for consumption and investment goods, p_c^1 and p_i^1 . p_c^1 is set at unity in order to ease the presentation of the model. The terms of trade θ_1 are defined as the ratio of the investment good price, p_i^1 , to the consumption good price, p_c^1 .¹³ The representative household may borrow or lend on a world capital market at the world interest rate r . Given these assumptions, the maximisation problem of the representative household can be written as

¹³ Note that:

θ_1 equals p_i^1 because p_c^1 has been set at unity.

$$[A1] \quad \text{Max! } W = U(C_1) + \beta U(C_2)$$

$$C_1, C_2, c, i, I$$

subject to

$$[A2] \quad Q(\bar{K}, \bar{L}, c) - i = 0$$

$$[A3] \quad C_1 + p_c^e C_2 - \theta_1 Q(\bar{K}, \bar{L}, c) - c - \alpha [p_c^e [f(\bar{K}, \bar{L}) + h(I)] - \theta_1 [r - \hat{p}_i^e] I] = 0$$

where β is the subjective discount factor, α equals one over one plus r , and \hat{p}_i^e is the expected rate of change of the price of the machine. It is assumed that production and utility functions exhibit the usual neoclassical properties so that¹⁴

$$U_C > 0, U_{CC} < 0; Q_C < 0, Q_{CC} < 0; h_I > 0, h_{II} < 0.$$

In addition, the following definitions hold

$$\theta_1 \equiv p_i^1 [p_c^1]^{-1}; \hat{p}_i^e \equiv [p_i^e - p_i^1] [p_i^1]^{-1}; \text{ and } p_c^1 = 1.$$

Equation [A2] is the production possibility frontier for producing the capital good and the consumption good in the first period. Equation [A3] is the intertemporal budget constraint (in terms of the first period price of the consumption good) which is derived by imposing the condition that the current account balance over time. This can be shown as follows. Define the real first period current account deficit b_1 as

$$[A4] \quad b_1 \equiv C_1 + \theta_1 I - \theta_1 Q(\bar{K}, \bar{L}, c) - c$$

¹⁴ Partial derivatives are expressed by a subscript so that the expression U_C denotes the partial derivative of the utility function with respect to consumption.

and the real second period current account deficit as

$$[A5] \quad b_2 = p_c^e [C_2 - f(\bar{K}, \bar{L}) - h(I)] - p_1^e I$$

where in both cases all nominal variables are divided by p_c^1 . The intertemporal budget constraint of the economy can be expressed in terms of b_1 and b_2 as

$$[A6] \quad b_1 + ab_2 = 0$$

Equation [A3] can now be derived by substituting equations [A4] and [A5] into equation [A6].

The first order conditions of the maximisation problem (equations [A1], [A2], and [A3]) are as follows:

$$[A7] \quad p_c^e h_I = \theta_1 [r - \hat{p}_1^e]$$

$$[A8] \quad U_C(1) = U_C(2) \beta [p_c^e a]^{-1}$$

$$[A9] \quad Q_c = - [\theta_1]^{-1}$$

where the notation $U_C(t)$, $t = 1, 2$ means that the explanatory variables of the marginal utility of consumption are evaluated at their period t equilibrium values. Equation [1'], the q-theoretic version of equation [A7], can be derived from [A7] by substituting the definition of \hat{p}_1^e .

By allowing for current account balances that differ from zero, equations [A4] and [A5] assume international capital mobility. If, on the other hand, international capital movements are ruled out, the current account has to balance in every period so that

$$[A4'] \quad 0 = C_1 + \theta_1 I - \theta_1 Q(\bar{K}, \bar{L}, c) - c$$

and

$$[A5'] \quad 0 = p_c^e [C_2 - f(\bar{K}, \bar{L}) - h(I)] - p_i^e I$$

In this case, optimality conditions [A7] and [A8] merge into one condition

$$[A7'] \quad p_c^e h_I = \theta_1 [U_c(1) p_c^e [U_c(2) \beta]^{-1} - 1 - \hat{p}_i^e]$$

which can be derived from [A7] and [A8] by eliminating the interest rate r which is no longer an exogenous variable in an economy closed to international capital movements.

The set of equations [A7] to [A9] along with the intertemporal budget constraint (equation [A3]) and the production possibility frontier (equation [A2]) implicitly define optimal values for C_1 , C_2 , I , c , and i . Notice that the decisions on the optimal product mix, the optimal pattern of consumption over time, and the optimal level of investment can be made independently of each other. They are a function of the exogenous variables r , β , θ_1 , p_c^e , and p_i^e . In order to assess the impact of changes of the exogenous variables on the endogenous variables a number of comparative static exercises can be performed. In order to do so, the the intertemporal budget constraint (equation [A3]) is substituted into the first order condition for optimality in consumption (equation [A8]) replacing C_2 . The total differential of the three first order conditions may then be calculated. Expressed in matrix form, the resulting set of three equations is

$$\begin{bmatrix} p_c^e h_{II} & 0 & 0 \\ 0 & 0 & U_{CC}(1) + AU_{CC}(2) \\ 0 & Q_{CC} & 0 \end{bmatrix} \begin{bmatrix} dI \\ dc \\ dC_1 \end{bmatrix} =$$

$$\begin{bmatrix} -h_I & [a]^{-1} \\ -\alpha A [U_C(2) + [p_c^e]^{-1} U_{CC}(2) [C_2^* - f(\bar{K}, \bar{L}) - h(I^*)]] & AU_{CC}(2) [Q^* - I^*] \\ 0 & [\theta_1]^{-2} \end{bmatrix}$$

$$\begin{bmatrix} \theta_1 & -1 \\ [p_c^e]^{-1} \beta U_C(2) - \alpha AU_{CC}(2) b_1^* & \alpha AI^* U_{CC}(2) \\ 0 & 0 \end{bmatrix} \begin{bmatrix} dp_c^e \\ d\theta_1 \\ dr \\ dp_i^e \end{bmatrix}$$

where $A = \beta [p_c^e]^{-2}$. An asterisk denotes an equilibrium value. Using Cramer's rule I calculate how the endogenous variables (I, c, C_1) change in response to shocks of the exogenous variables. The results are summarized in Table A1.

Table A1- External Shocks and the Small Open Economy:
Size and Direction of Effects on Dependent Variables¹⁵

Independent Variable	Change in	Size of Effect	Sign of Effect
Investment (I)	θ_1	$[a]^{-1} [B] [\Delta]^{-1}$	< 0
	r	$\theta_1 [B] [\Delta]^{-1}$	< 0
	p_c^e	$-h_I [B] [\Delta]^{-1}$	> 0
	p_i^e	$-B [\Delta]^{-1}$	> 0
Production of Con- sumption Good (c)	θ_1	$-[\theta_1]^{-2} E[U_{CC}(1)+AU_{CC}(2)] [\Delta]^{-1}$	< 0
	r	0	
	p_c^e	0	
Current Account Deficit (Period 1) (b_1)	θ_1	$-Q_{CC} [E[-U_{CC}(1) [Q^*-I^*]] - [a]^{-1} [D]] [\Delta]^{-1}$	< 0 if $Q^* > I^*$ > 0 if $Q^* < I^*$
	r	$-Q_{CC} [E[\beta [p_c^e]^{-1} U_C(2) - aAU_{CC}(2) b_1^*] - [\theta_1] [D]] [\Delta]^{-1}$	< 0 if $b_1^* > 0$ > 0 if $b_1^* < 0$
	p_c^e	$-Q_{CC} [E[-aA[U_C(2) + [p_c^e]^{-1} U_{CC}(2) [C_2^* - Y_2^*]]] + [h_I] [D]] [\Delta]^{-1}$	> 0 if $C_2^* < Y_2^*$ > 0 if $C_2^* > Y_2^*$
	p_i^e	$-Q_{CC} [EaAI^*U_{CC}(2) + D] [\Delta]^{-1}$	> 0
Consumption (Period 1) (C_1)	θ_1	$[I^* - Q^*] [Q_{CC} EAU_{CC}(2)] [\Delta]^{-1}$	> 0 if $Q^* > I^*$ < 0 if $Q^* < I^*$
	r	$[-Q_{CC} E[\beta [p_c^e]^{-1} U_C(2) - aAU_{CC}(2) [b_1^*]]] [\Delta]^{-1}$	< 0 if $b_1^* > 0$ > 0 if $b_1^* < 0$
	p_c^e	$Q_{CC} E[aA[U_C(2) + [p_c^e]^{-1} U_{CC}(2) [C_2^* - Y_2^*]]] [\Delta]^{-1}$	> 0 if $C_2^* < Y_2^*$ > 0 if $C_2^* > Y_2^*$
	p_i^e	$[-Q_{CC} EaAI^*U_{CC}(2)] [\Delta]^{-1}$	> 0
Wealth (W^*)	θ_1	$\beta [p_c^e a]^{-1} U_C(2) [Q^* - I^*]$	> 0 if $Q^* > I^*$ < 0 if $Q^* < I^*$
	r	$-\beta U_C(2) [p_c^e]^{-1} [b_1^*]$	> 0 if $b_1^* > 0$ < 0 if $b_1^* < 0$
	p_c^e	$-[p_c^e]^{-1} \beta U_C(2) [C_2^* - Y_2^*]$	> 0 if $C_2^* < Y_2^*$ > 0 if $C_2^* > Y_2^*$
	p_i^e	$[p_c^e]^{-1} \beta U_C(2) I^*$	> 0

¹⁵ Symbols not previously used are defined as follows:

$D \equiv -\theta_1 [U_{CC}(1) + AU_{CC}(2)] > 0$; $E \equiv p_c^e h_{II} < 0$; $\Delta \equiv -EQ_{CC} [U_{CC}(1) + AU_{CC}(2)] > 0$;
 $B \equiv \Delta [E]^{-1} < 0$; $Y_2^* \equiv f(\bar{K}, \bar{L}) + h(I^*) > 0$.

It follows from equations [A4] that the change of the current account deficit in the first period in response to an exogenous shock is

$$[A10] \quad b_{1x} = C_{1x} + \theta_1 I_{1x} - [Q^* - I^*] d\theta_1$$

where subscript x represents the derivative with respect to the exogenous variable x. Using equation [A10] and the results of Table A1 it can be shown that the impact effects of exogenous shocks on the current account deficit in the first period are as reported in Table 1. The effect on the second period current account deficit follows from the intertemporal budget constraint (equation [A6]) which implies that

$$[A11] \quad b_{2x} = -[a]^{-1} b_{1x}$$

so that the change in the current account deficit in period 2 in response to an exogenous shock is negatively proportional to the first period response.

The envelope theorem can be used to ascertain the effect of the various shocks on the overall wealth of the economy. Let W^* be defined as

$$[A12] \quad W^* = W(C_1^*, C_2^*)$$

where W^* is the maximum level of utility of the utility function (equation [A1]) for a given set of exogenous parameters. C_1^* and C_2^* therefore are solutions to the maximization problem of equations [A1] to [A3]. The envelope theorem states that in this case

$$[A13] \quad dW^*/dx = \delta W/\delta x$$

where x is any one of the exogenous parameters. Using equations [A1], [A4] and [A5] it is possible to evaluate equation [A13] for different external shocks. The results are given in Table A1.

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