POLSKA AKADEMIA NAUK
INSTYTUT BADAŃ SYSTEMOWYCH

PROCEEDINGS OF THE 3rd ITALIAN-POLISH CONFERENCE ON APPLICATIONS OF SYSTEMS THEORY TO ECONOMY, MANAGEMENT AND TECHNOLOGY

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SOME ISSUES ON APPLICATION OF CONTROL THEORY TO BALANCE OF PAYMENTS ADJUSTMENT: A NEW TREATEMENT OPPOSED TO THE ACCEPTED THEORY

The dominant theory of balance of payments adjustment (known as the Tinbergen-Mundell Approach) has recently become the object of serious criticism.

Not only, as it was observed since long, it is inadequate to face the problems of less developed countries; but, after the oil crisis with its tremendous impact on balance of payments equilibria of many industrialized countries, it appears questionable and lacking even for the capitalistic world[1]).

The dissatisfaction with the present state of the theory, however, has not arisen merely from political or empirical facts, but it is deeply rooted in the analysis of its own foundations.

Briefly, the accepted theory which relies on a targets-instruments approach in order to achieve both "internal and external balance" of an economy, suffers from important limitations; it does not maximize any definite social welfare function and it may result destabilizing for the economy even when instruments are appropriately paired with the objectives on which they have the most influence.

The present paper after a summary of Mundell's strategy to obtain external and internal balance, with a comment on its inadequacies, deals with an alternative approach based on an application of control theory to problems of balance of payments adjustment.

While the former approach follows a logic which is essentially static; the latter consists in a process of intertemporal maximization of a social welfare function, from which prescriptions for balance of payments are derived.

A mathematical model illustrates the problems and outlines the main results obtained from this new approach.

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In a famous paper: "The appropriate use of monetary and fiscal policy for internal and external stability", Mundell stated that it was possible to

[1]) See M. Arcelli: Sviluppo Economico, scambi internazionali e crisi monetaria — Atti della 15 Riunione Scientifica della Societa Italiana degli Economisti, Giuffre 1975.

attain both internal stability and balance of payments equilibrium by an appropriate choice of the mix of fiscal and monetary policy.

Internal balance is defined as equilibrium between aggregate demand and supply at full employment. The demand is assumed to be inversely related both with fiscal policy (measured by high-employment budget surplus g) and monetary policy (measured by the interest rate r). It is then possible to trace a locus of points of internal balance in the g/r plane, downward sloping (IB).

Also the balance of payments equilibrium depends on interest rate and budget surplus: capital flows are assumed to be responsive to interest rate differentials and the balance of trade is inversely related with the level of domestic expenditure and therefore depends on g.

The locus of points of external balance in the g/r plane (EB) is steeper than IB, as the increase of interest rate requires a decrease in the budget surplus to achieve the external balance more consistent than the one which is necessary for internal balance (capital flows being responsive to interest rate differentials).

Hence the curves IB and EB must intersect at some point in the g/r plane where it is possible to attain both internal and external balance.

Mundell stresses that when the exchange rate is fixed and monetary and fiscal policy can be used as independent instruments to attain the two targets, monetary policy ought to be aimed at external objectives and fiscal policy at internal goals.

The failure to follow such prescription might worsen the disequilibrium situation preceding the policy changes. In other words: "policies should be paired with the objectives on which they have the most influence. If this principle is not followed, there will develop a tendency either for a cyclical approach to equilibrium or for instability".

Thus Tinbergen's principle that in order to attain a given number of independent targets it is necessary to dispose at least of an equal number of instruments, refers only to the problem of existence of a solution to the system. It does not guaranteed that any given set of policy will lead to that solution. Mundell's strategy is an integration to Tinbergen's principle, investigating the stability properties of a dynamic system.

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The so called Tinbergen-Mundell approach has largely dominated the theoretical debate of economic policy of western economies during the sixties. The prescriptions to follow were that "a surplus country experiencing inflationary pressure should ease monetary conditions and raise taxes (or reduce government spending), whereas a deficit country suffering from unemployment should tighten interest rates and lower taxes (or increase government spending)".

To a certain extent this policy has been also implemented. A main implication of this approach is the neglect to consider as a separate target the balance of current accounts, since attention is devoted to global external equilibrium.

Consequently current accounts deficits may be countered by capital inflows thereby progressively raising foreign indebtedness. The possibility to attain

external balance without restoring trade balance, also encourages a slack domestic policy, which endangers price-stability.

Briefly to attain the two targets (internal and external balance) in a given moment does not imply that a welfare function is maximized; neither the approach is necessarily consistent with long run objectives.

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The inadequacy of Mundell's strategy for less developed countries had always been recognized. For these countries the trade deficit is a structural characteristic and interest rate differentials are not sufficient to attract the needed foreign investments. More recently, however, the impact of oil crisis has raised many questions about the feasibility of Mundell's approach also for many capitalistic countries.

Not only the so-called dominant theory appears concerned with a global external balance, neglecting current accounts situations and long run objectives; but it also shows powerless when confronted with the huge deficits induced by sudden crude oil prices growth.

Stagflation is a farther complication in the working of modern economies which makes out of date the simple rules prescribed by Mundell.

So it is not surprising that in the present situation Mundell's theory is under severe scrutiny, while alternative approaches to balance of payments adjustments are carefully considered.

The criticism of Mundell's approach however reached its zenith well before the oil crisis. At the Sheffield Seminar on Monetary Theory and Monetary Policy in the 1970's, held in September 1970, Williamson presented a paper "On the normative theory of balance of payments adjustment" that on one hand pushed farther the dissatisfaction with the targets-instruments approach on theoretical grounds; while providing on the other hand an alternative approach based on an application of control theory to balance of payments adjustment.

Williamson argued that international capital movements are better described by a stock adjustment theory than by a flow theory. But even if long term capital movements were sufficiently well described by a flow theory to save the model as a positive model, Mundell's strategy would deserve no status as normative economics.

Should one consider a multiperiod analysis, then one would realize that in many cases the trajectories traced out by Mundell's prescriptions from differing initial conditions necessarily diverge.

A less competitive economy will have a less favourable current account at the designated unemployment level. The internal balance will therefore require a more relaxed fiscal monetary policy mix; whereas on the contrary external balance will require tighter interest rates to attract more capital. Fiscal policy will be looser, monetary policy tighter and foreign debt greater than in the case of a more competitive economy.

IB would by pushed inwards and EB outwards in the g/r plane. This trend would be reinforced in the following periods because the interest burden of

foreign debt and the progressively falling competitiveness. of the economy owing to a lower investment-product ratio. So IB would be pushed more and more inwards and EB outwards. Instability would be the final outcome of Mundell's strategy[2]).

Indeed Professor Johnson had already remarked that a policy of manipulating the capital account to counter current accounts deficits was scarcely likely to lead to an efficient pattern of international investment.

Two partial conclusions therefore emerge at this point: first the targets--instruments approach proposed by Mundell does not maximize any welfare function: second an efficient mechanism of balance of payment adjustments must explicitly refer to the current account.

Williamson in his paper shows that the optimal trajectories that result from maximizing intertemporal welfare starting from different initial conditions converge asymptotically in a wide range of problems. Hence the limitations of Mundell's approach can be overcome according to Williamson, by constructing a social welfare function that is a reasonable reflection of the ultimate ends of the economic system and maximizing this, subject to the constraints imposed by the positive economy. Appropriate values of proximate objectives are then obtained as a by-product of intertemporal maximization.

Whereas a targets-instruments approach does not necessarily reconcile and may even bring about conflicts between short run and long run objectives in national economy. Williamson's approach renders consistent to-day decisions with to-morrow measures. Moreover it gives due attention to current account balances and hence to the change in foreign indebtedness which are neglected in the simplified Mundellian approach.

Following this new stream, in this paper it is described a model which may be considered a variant of Williamson's approach.

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I propose to maximize intertemporally a social welfare function where the utility depends on the level of consumption and on income distribution, subject to income determination equations which give substantial weight to the constraints of an open economy.

The process of maximization consists in an application of the maximum principle to the objective function where consumption and labour share are treated like control variables, whereas foreign indebtedness, capital stock and index of competitiveness are state variables.

The model and its asymptotic solutions are exposed in details in the following pages.

The adjustment process is to be interpreted as one where-by the policy makers return the economy to its asymtotically opitmal trajectory from initial conditions off this path.

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[2] This kind of instability is different from the short run instability discussed by Mundell and related to the fact the instruments are not rationally paired with objectives.

Given the complexity of the model I have limited the analysis to the steady state solutions: the presence in the model of three state variables excluded the customary solution by phase diagram.

The results obtained are in line with, but not the very same. Williamson's conclusions: comments on them, follow the model.

Here I want to point out that simplifications and improvements may be found in the formulation of the objective function and in the differential equations. In particular the price equation has been made consistent both with cost-push inflation situations and demand pull inflations.

Besides, and I believe with more adherence to reality (at least for Italy), the model considers changes in foreign debt rather than in foreign assets accumulation.

The model, however, ought to be considered only as an instance of this new kind of approach. It lacks in realism in many respects and further improvements should be introduced with due consideration for monetary and financial aspects, for expectations and by suitable disaggregation.

NOTATION

Variables

C = Consumption
D = Foreign Debt (in foreign currency)
E = Exports
H = Hamiltonian
J = Welfare function
I = Gross Investment
K = Capital Stock
M = Imports
P = Price level
R = Interest charge on foreign debt
T = Trade balance
W/Y = Labour income share
X = Exchange rate
Y = Gross national product
Π = Index of competitiveness
ϱ = Foreign rate of inflation
U = Utility

Parameters

a = Exports-competitiveness marginal ratio
b = Imports-competitiveness marginal ratio
$c = a+b$
d = Rate of depreciation
e = Elasticity of internal price level with respect to international commodities prices
i = Elasticity of internal price level with respect to income distribution
m = Marginal propensity to import
$n = \frac{m}{1+m}$; $h = \frac{c}{1+m}$
q_i = Shadow price of i constraint or costate variable
r = Rate of time preference

THE MODEL

$$\max \bar{J} = \int U[C(t), W\ Y(t)]\, e^{-rt}\, dt \tag{1}$$

$C(t)$ and $W/Y(t)$: control variables, piecewise continuous function of time; $0 \leqslant C(t) < f(K_t)$; $0 \leqslant W/Y \leqslant 1$
X (exchange rate): additional control variable (not necessarily used).
$D(t)$, $K(t)$, $\Pi(t)$: state variables.

$$\frac{\delta U}{\delta C} > 0; \quad \frac{\delta^2 U}{\delta C^2} < 0; \quad \frac{\delta U}{\delta W/Y} > 0; \quad \frac{\delta^2 U}{\delta W/Y^2} < 0$$

Subject to:
Income determination equations:

$$Y = C + I + T \tag{2}$$

$$Y = f(K) \tag{3}$$

$$T = T(Y, \Pi) = E - M \tag{4}$$

$$M = mY - b\Pi \qquad \text{(in national currency, real values)} \tag{5}$$

$$E = E^* + a\Pi \qquad E^*\text{: exogenously determined} \tag{6}$$

Hence

$$T = \frac{E^*}{1+m} - \frac{m}{1+m}(C+I) + \frac{c}{1+m}\Pi$$

$$T = \frac{E^*}{1+m} - n(C+I) + h\Pi \tag{7}$$

Differential equations:

$$\dot{\Pi}/\Pi = \varrho^* + \dot{X}/X - \dot{P}/P \qquad \varrho^*\text{: exogenously determined} \tag{8}$$

$$\dot{P}/P = [e(\varrho^* + \dot{X}/X + i(W/Y)'/W/Y] \tag{9}$$

$$\dot{K} = I - dK \tag{10}$$

$$\dot{D} = R(D) - \frac{T}{X} \qquad \text{(Remembering that } D \text{ is expressed in foreign currency)} \tag{11}$$

Initial conditions $\Pi_0 = \bar{\Pi}$; $K_0 = \bar{K}$; $D_0 = \bar{D}$

From (8) and (9):

$$\Pi/\Pi = [(1-e)(\varrho^* + \dot{X}/X) - i(W/Y)'/W/Y] \tag{12}$$

From (11) and (7):

$$D = R(D) - \frac{1}{X}\left[\frac{E^*}{1+m} - n(C+I) + h\Pi\right] \tag{13}$$

Hamiltonian

$$H = e^{-rt}\Big\{U(C, WY) + q_1[I - dK] + q_2[(1-e)(\varrho^* + \dot{X}/X) - i(W/Y)\,/W/Y]\,\Pi + \\ + q_3\left[-R(D) + \frac{1}{X}\left(\frac{E^*}{1+m} - n(C+I) + h\,\Pi\right)\right]\Big\}$$

Optimum conditions (assuming interior solutions) and derived steady state solutions are:

$$\text{a)}\quad \frac{\delta H}{\delta C} = U_1 - q_3\frac{n}{X} = 0 \quad \text{hence} \quad U_1 = q_3\frac{n}{X} \tag{14}$$

The marginal utility of consumption must be equal to the imputed price (shadow price) of foreign debt which accrues from a worsened trade balance. I is supposed to be independent from C: the consistency of the optimum conditions of the model implies in this case that the accumulation of capital is non-optimum.

If, on the other hand, at the limit any change in C is compensated by an equal change of opposite sign in I, equation (14) is replaced by:

$$\frac{\delta H}{\delta C} = U_1 - q_1 = 0 \quad \text{hence} \quad U_1 = q_1 \tag{14 bis}$$

The marginal utility of consumption must be equal to the imputed value (shadow price) of marginal capital accumulation.

$$\text{b)}\quad \frac{\delta H}{\delta W/Y} = U_2 - q_3\frac{h}{X}\,i\,\frac{\Pi}{W/Y} - \frac{q_2\,i\,\Pi}{W/Y}\left[\frac{\dot{\Pi}}{\Pi} - (W/Y)'/W/Y\right] = 0$$

$$\text{hence}\quad U_2 = q_3\frac{h}{X}\,i\,\frac{\Pi}{W/Y} + \frac{q_2\,i\,\Pi}{W/Y}\left[\frac{\dot{\Pi}}{\Pi} - (W/Y)'/W/Y\right] = 0 \tag{15}$$

The marginal utility of a preferred income distribution must be equal to the marginal disutility (shadow price) of foreign debt which accrues from a worsened trade balance due to a loss of competitiveness, plus the imputed value of a lower competitiveness determined by increased internal prices. In steady state the last term of the right side of equation (15) vanishes.

The canonical equations for the costate variables:

$$\text{c)}\quad \frac{d}{dt}\left(e^{-rt}q_1(t)\right) = -\frac{\delta H}{\delta K}$$

$$\dot{q}_1 e^{-rt} - r e^{-rt} q_1 = -q_1[f'(K) - d]e^{-rt} + q_3\frac{n}{X}f'(K)e^{-rt}$$

$$\dot{q}_1 = q_1[r + d - f'(K)] + q_3\frac{n}{X}f'(K) \tag{16}$$

In equilibrium (steady state) equation (16) implies $f'(K) > r+d$ provided $q_3 > 0$: that is the marginal productivity of capital is greater than the rate of time preference plus the depreciation rate (modified golden rule). Hence the accumulation is suboptimal.

If however the objective functional has become insensitive to small changes of the value of the state variable D, then $q^* = 0$ and the modified golden rule is verified

d) $$\frac{d}{dt}\left(e^{-rt} q_2(t)\right) = -\frac{\delta H}{\delta \Pi}$$

$$\dot{q}_2 e^{-rt} - r q_2 e^{-rt} = -q_3 \frac{h}{X} e^{-rt} - q_2 e^{-rt}[(1-e)(\varrho^* + \dot{X}/X) -$$

$$- i(W/Y)'/W/Y]$$

$$\dot{q}_2 = q_2 r - q_3 \frac{h}{X} - q_2[(1-e)(\varrho^* + \dot{X}/X) - i(W/Y)'/W/Y] \tag{17}$$

In equilibrium (steady state) the third term of the right side of equation (17) varishes. Equation (17) then reduces to:

$$q_2 r = q_3 \frac{h}{X} \tag{18}$$

that implies that the shadow price of foreign asset times $\frac{h}{X}$ must be equal to the shadow price of competitiveness times the rate of time preference.

Notice that in steady state $q_2 > 0$ implies that competitiveness is undesiderably low.

e) $$\frac{d}{dt}\left(e^{-rt} q_3(t)\right) = -\frac{\delta H}{\delta D}$$

$$\dot{q}_3 e^{-rt} - r e^{-rt} q_3 = -q_3 R'(D) e^{-rt}$$

$$\dot{q}_3 = q_3(r - R') \tag{19}$$

In steady state equation (19) implies that the level of foreign debt is such that the marginal cost is equal to the rate of time preference.

Additional control variable

$$\frac{\delta H}{\delta X} = q_3 h(1-e)\frac{\Pi}{X^2} - q_3 \frac{T}{X^2} + q_2(1-e)\frac{\Pi}{X} - q_2(1-e)\frac{\dot{X}}{X^2} = 0$$

that gives

$$q_3 \frac{h}{X}\left(1 - \frac{T}{h(1-e)\Pi}\right) + q_2 \frac{\dot{\Pi}}{\Pi} - q_2 \frac{\dot{X}}{X} = 0$$

hence

$$\text{f)}\quad q_3 \frac{h}{X}\left(1-\frac{T}{h(1-e)\Pi}\right) = -q_2\left(\frac{\dot{\Pi}}{\Pi}-\frac{\dot{X}}{X}\right) \tag{20}$$

In steady state the rate of change of competitiveness and the rate of change of exchange rate are null.

Equation (20), to be consistent, implies therefore that $q_3 = 0$. With reference to equation (16) that implies that the modified golden rule is verified and accumulation of capital becomes optimal.

When the internal rate of inflation, during the transitory period before asymptotic solution, is not consistent with the international rate of price growth then the accumulation of capital remains sub-optimal; but with adequate exchange rate manipulation optimal conditions are reestablished.

The main results of the model may be summarized as follows:

1) In optimum conditions (equilibrium), it is necessary to attain a trade surplus sufficient to pay for interests on foreign debt.

According to equation (19) optimal foreign indebtedness depends on domestic rate of time preference and on marginal cost of foreign debt.

A rise in the marginal cost of foreign debt would decrease the level of foreign indebtedness in steady state by equation (14) that would imply a larger steady state consumption and by equation (15) a more preferred income distribution.

An increase in the rate of time preference would on the other hand raise the steady-state foreign indebtedness and conversely decrease steady-state consumption and worsen income distribution.

The trade surplus in steady-state would be lesser in the former case and greater in the latter.

It must be underlined that a change in the initial level of foreign debt D would not have any influence on steady state solution.

At time zero foreign payments deficits would be larger for a higher rate of time preference and consumption too would be larger.

A rise in the marginal cost of foreign debt would instead require during transition less payments deficits or larger surplus if the initial $\bar{D} > D^*$ (steady-state indebtedness).

2) In equilibrium the marginal utility of consumption is equalled either to: a) the imputed value of foreign debt which accrues from a worsened trade balance (equation (14)); or b) to the shadow price of marginal capital accumulation (equation (14 bis)). This latter condition is active when accumulation is optimal.

In that case equation (16) states that the net marginal productivity of capital is equal to the rate of time preference. In accordance to equation (19) also the marginal cost of foreign debt must be equal to the rate of time preference: thus in steady-state the level of capital accumulation and consumption are strictly related to foreign indebtedness.

A change in the rate of time preference or in the marginal cost of foreign debt will therefore vary both capital accumulation and consumption of steady state inversely as foreign indebtednese.

3) Often however, the accumulation is sub-optimal: the marginal productivity of capital is greater than the rate of time preference plus the depreciation rate (modified golden rule). That happens when the desired internal rate of inflation is superior to the international one. If fixed exchange rate is maintained the country will suffer from welfare loss: it cannot achieve the mix of absorption and inflation that it would prefer, given the balance of payments constraint, and will indulge in sub-optimal accumulation since it is forced to accept a lower level of real income.

With adequate exchange rate manipulation, however, the required degree of competitiveness is attained and thereby conditions for optimal accumulation are reestablished. Notice that low competitiveness and sub-optimal accumulation are two faces of the same problem (equation (1^0)).

4) Foreign currency reserves have not explicitly mentioned in the working of the model: in steady state their role is null, whereas their function may be relevant during transmission.

They enable a country to avoid adjusting to transitory disturbances or help to optimize the rate of adjustment. Under fixed exchange rate, they allow to avoid income deflation under the internally optimal level while a given dual improvement in competitiveness is achieved.

Managed floating, an active exchange rate policy, fulfills a similar task: it reconciles external and internal objectives (like attainment of a preferred income distribution) and, as we have seen, it also creates conditions for optimal capital accumulation, allowing for a higher welfare level.

5) The intertemporal maximization of a social welfare function excludes the indiscriminate recourse to capital inflows as a permanent means to offset current accounts deficits.

Indeed manipulation of capital accounts have no influence on desirable steady state solution. This conclusion does not prevent the use of interest rate policy to attract capitals during transition as a form of quasi-adjustment to solve temporary scarcity of foreign currency. This approach however must carefully take into account the distorsions it causes to the desirable consumption--investment mix.

6) Among all possible exercises in comparative dynamics, it is interesting to analyze the effects of a change in the parameter **n** (which depends on marginal propensity to import).

It is possible to show that an increase in the marginal propensity to import would reduce steady state consumption. See Appendix for proof.

7) The whole story-optimal trajectories of the variables and steady state solution — hinges on how the welfare function has been specified, that is on which objectives have been included in the function and the weight attributed to them.

The difficulty to specify a welfare function which reflects the ultimate ends of the society accurately and realistically, may induce some skepticism on the validity of the previous analysis.

The constraining functions too, are too schematic in order to provide an adequate framework for decisionmaking.

I think neverthless that the previous approach allows at least a critical assessment of the existing doctrine on desirable adjustment policies of balance of paymentic.
In this perspective I consider a major result to have pointed out the fallacies of Mundell's prescriptions, by showing that capital inflows have no influence on steady state solutions: therefore they cannot be employed as permanent measures to offset current account deficits.
Mundell's strategy may be on the contrary seriously distorting and can contribute to bring the economy farther off the optimal path, hereby increeasing disequilibria.
The welfare maximization approach is distinctly superior in this respect as it makes short run decisions consistent with long run objectives: it outlines a method which ought to be followed in any decision-making.

APPENDIX

A verbal proof may be given showing that by equation (19) in steady state the level of foreign debt depends only on the rate of time preference and on the marginal cost of indebtedness. Steady state consumption is defined by equation (14).

It follows that the level of consumption depends inversely on the value of the parameter **n**. An increase in **n** (determined by an increase in the propensity to import) will therefore produce a decrease in the steady state consumption.

$$\frac{\delta H}{\delta C} = U_1 - q_3 \frac{n}{X} = 0 \qquad (14)$$

deriving with respect to n gives

$$U_{11} \cdot \frac{\delta C}{\delta n} = \frac{q_3}{X} + \frac{n}{X} \cdot \frac{\delta q_3}{\delta n}$$

In steady state $\frac{\delta q_3}{\delta n} = 0$; therefore

$$\frac{\delta C}{\delta n} = \frac{q_3}{X} \frac{1}{U_{11}} \quad \text{but} \quad U_{11} < 0$$

hence

$$\frac{\delta C}{\delta n} < 0$$

SUMMARY

The dominant theory of balance of payments adjustment (known as the Tinbergen-Mundell approach) has recently become the object of serious criticism. Mundell's strategy to reconcile "internal and external balance" by means of a targets-instruments analysis suffers from important limitations.

It cannot maximize any relevant welfare function and it may result destabilizing for the economy even when instruments are appropriately paired with the objectives on which they have the most influence. Hence Williamson's proposal to submit the balance of payments adjustment to the prescriptions derived from the application of control theory.

This approach consists in an intertemporal maximization of a social welfare function, subject to the constraints imposed by the working of an open economy.

Appropriate values of proximate targets are derived as a by-product of intertemporal optimization.

The present paper illustrates a simple model of an open economy with an application of the maximum principle to a social welfare function. The model is a variant of Williamson's analysis and allows the assessment of interesting economic theorems. The analysis focuses on steady-states solutions.

The discussion of the implications and limitations of this kind of approach closes the paper.

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