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**Asset Accumulation, Fertility
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Dynamics in a
Small Open Economy**

Alberto Petrucci

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Asset Accumulation, Fertility Choice and Nondegenerate Dynamics in a Small Open Economy

Summary

This paper shows that the assumption of elastic fertility choices represents an unconsidered way of introducing nondegenerate dynamics within an immortal small open economy, facing perfect capital mobility and no adjustment costs associated with capital accumulation, and having a fixed discount rate. The transient dynamics are obtained since fertility, which enters the Euler equation, renders the growth of the marginal utility of wealth strictly interconnected with wealth accumulation. The comparative dynamics are studied for two exogenous shocks: an increase in thrift, which changes fertility and capital formation permanently, and an increase in government spending, which alters fertility and capital stock temporarily.

Keywords: Endogenous population, Capital accumulation, Current account, Transitional dynamics

JEL Classification: E21, E62, H22

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1 Introduction

A small open economy peopled by infinite-lived maximizing consumers with a constant rate of time discount, operating in a world of perfect financial capital mobility, in which capital formation is absent or, if endogenous, does not involve adjustment costs, exhibits degenerate dynamics. Degenerate dynamics means that the economy is always in the steady state and jumps instantaneously from one equilibrium to another, with no transitional dynamics if an exogenous shock occurs; see Giavazzi and Wyplosz (1984), Blanchard and Fischer (1989), and Turnovsky (1997).

The degeneracy of the dynamics derives from the pathological structure taken by the Euler equation, which, by ensuring the intertemporal arbitrage condition between consumption and wealth returns, governs the growth in the marginal utility of wealth. In the context just described, such Euler equation implies a constant marginal utility of wealth, as the given world interest rate must be set arbitrarily equal to the fixed rate of subjective time discount, in order to have an interior finite steady state. This strong implication renders the state matrix of the dynamic system singular as the eigenvalue associated with the predetermined variable, i.e. net foreign assets, is zero. This problem is known in the literature as the "zero root problem"; see, for a methodological discussion, Giavazzi and Wyplosz (1985) and Buiter (1986).

There are several operative ways to introduce some sluggishness into this small open economy with the scope of making the eigenvalue associated with

the predetermined variable nonzero and thereby obtaining nondegenerate dynamics. Specifically, transitional dynamics can be obtained by considering in turn:¹ i) an endogenous subjective rate of time preference (see Obstfeld, 1981 and 1982a); ii) imperfect asset substitutability and/or capital mobility (see Obstfeld 1982b, Turnovsky, 1987, and Bhandari, Haque and Turnovsky, 1990);² iii) overlapping-generations demographics (see Blanchard, 1984 and 1985, and Obstfeld, 1989); iv) convex adjustment costs for capital accumulation (see Blanchard and Fischer, 1989, and Sen and Turnovsky, 1989a and 1989b); and v) habit-forming preferences (see Obstfeld, 1992, and Mansoorian, 1993).

Procedures i), ii) and iii) introduce some inertia into the economy by affecting the Euler equation directly,³ while procedures iv) and v) generate saddle-point dynamics by leaving the "Keynes-Ramsey rule" unaffected and considering *de facto* additional dynamic variables, like the Tobin q or the habitual standard of living, respectively.⁴

The objective of this paper is to show that the assumption of elastic fertility choices, which renders population growth endogenous, represents an

¹A comprehensive survey of the different procedures that make it possible to overcome the "zero root problem" is provided by Turnovsky (1997, chapters 1 and 2).

²This hypothesis can be implemented by considering either brokerage costs for holding foreign assets or an upward-sloping supply curve of debt.

³In particular, procedure i) makes the rate of time preference a function of the utility level *à la* Uzawa, procedure ii) instead, renders the domestic interest rate endogenous, while procedure iii) introduces a wedge between the world interest rate and the rate of time preference that depends on the consumption-wealth ratio.

⁴Note that the sources of sluggishness considered by procedures iv) and v) imply that the steady state model depends on the initial conditions.

additional mode (unconsidered before) of introducing nondegenerate dynamics within an infinite-horizon small open economy, facing a perfect world financial market and having a fixed discount rate. The crucial element that invalidates the degeneracy of the dynamics in this economy is a demand for fertility that depends on financial wealth in the short-run; the introduction of endogenous population growth in the Euler-Keynes-Ramsey condition, by making the marginal utility of wealth variable in the short-run, avoids the arbitrary equalization of the rate of time preference to the given world interest rate.

The dynamic behavior of this economy is studied for two exogenous shocks: i) an increase in thrift; and ii) an increase in government spending. Although these two disturbances exert differentiated long-run consequences on the economy, they have common features regarding the short-run behavior. An increase in thrift, i.e. a decline in the rate of time discount, alters consumption, fertility and capital stock permanently, while an increase in government spending affects consumption permanently, while affecting fertility and capital stock only temporarily. In both cases, we observe saddle-point dynamics, characterized by perverse-shooting of the jumping variables on impact, i.e. high impact volatility of the system after an unexpected disturbance takes place, followed by monotonic convergence (in the opposite direction) towards the long-run equilibrium.

The paper is organized as follows. Section 2 presents the setup. Section 3 analyzes the property of stability, while Section 4 examines the steady state and dynamic effects of exogenous disturbances. Section 5 makes some concluding remarks.

2 The model

Consider a real small open economy populated by competitive firms and infinite-lived consumers that accumulate wealth in the form of physical capital and net foreign assets. This economy produces a single tradable good, perfectly substitutable with the foreign produced good, and operates in a perfectly integrated world capital market.

Population expands endogenously. This is obtained by allowing the fertility rate, inserted into the utility function of consumers, to be endogenously chosen, as in Razin and Ben-Zion (1975), Barro and Becker (1989), and Palivos (1995).

The representative consumer's objective is to maximize the functional

$$\int_0^{\infty} [U(c) + V(n)]e^{-\delta t} dt \quad (1)$$

subject to the time allocation constraint

$$l + T(n) = 1, \quad (2)$$

the flow budget constraint

$$c + \dot{a} = (r^* - n)a + wl - q, \quad (3)$$

and the condition $a(0) = a_0 > 0$. The notation employed in the problem (1)-(3) has the following interpretation: c is per capita consumption, n the fertility rate, δ the rate of time preference (constant), l labor hours per capita, $T(\cdot)$ time spent for child-rearing, a per capita wealth, r^* the world interest rate (exogenous), w real wage, and q per capita lump-sum taxes.

The instantaneous utility function, assumed to be additively separable in consumption and fertility, is twice-continuously differentiable, increasing and strictly concave in its arguments.⁵ The fertility rate corresponds to population growth because the mortality rate is assumed to be zero and no immigration from the rest of the world is considered.

According to the time allocation constraint (2), the fixed time endowment (normalized to one) can be divided between labor and child-rearing.⁶ The function $T(n)$ represents the time cost of child-rearing, with $T(0)=0$ and, for $n>0$, $T>0$, $T'>0$, and $T'' \geq 0$.

Optimality requires

$$U'(c) = \lambda \tag{4a}$$

$$V'(n) = \lambda[wT'(n) + a] \tag{4b}$$

$$\dot{\lambda} - \lambda\delta = -\lambda(r^* - n), \tag{4c}$$

where λ is the shadow value of wealth. The time allocation constraint (2), the flow budget constraint (3) and the transversality condition $\lim_{t \rightarrow \infty} ae^{-\delta t} = 0$ must also be satisfied at the optimum.

⁵If preferences were not separable in consumption and fertility, no changes in our results would be obtained provided that consumption and fertility are normal goods.

⁶See Wang, Yip and Scotese (1994), and Palivos (1995). Barro and Sala-i-Martin (2003), instead, consider a child-rearing cost function (which depends directly on n and k) in the budget constraint of the representative consumer. Our results would remain unaltered under the Barro and Sala-i-Martin approach.

The first two equations (4a)-(4b) are the static efficiency conditions. Equation (4b) asserts that the marginal rate of substitution of consumption for fertility must equal the opportunity cost of one unit of fertility, given by the wage rate times the marginal time-cost of child-rearing plus per capita wealth. Equation (4c), deriving from the intertemporal arbitrage relationship, is the Keynes-Ramsey rule.⁷

Per capita nonhuman wealth consists of per capita capital stock k and per capita net foreign assets b , i.e. $a = k + b$. b may be either positive or negative, while a is considered to be strictly positive.

Firms operate in competitive factor and output markets; they produce domestic output y (expressed in per capita terms) by using capital and labor as inputs through the production function $y = F(k, l)$, which satisfies the usual properties of regularity and exhibits constant returns to scale.

Maximum profit requires:

$$F_k(k, l) = r^* \tag{5a}$$

$$F_l(k, l) = w. \tag{5b}$$

Since $F(\)$ is linearly homogeneous, we can write $F(k, l) = lf(\frac{k}{l})$, with $f' > 0$ and $f'' < 0$. The world interest rate ties down capital intensity and hence the wage rate; therefore, we have

$$k = \kappa^* l \tag{5a'}$$

⁷As has been emphasized in the Introduction, the presence of the endogenous fertility rate in (4c) avoids the short circuit of the dynamics in the economy.

$$w = \omega^*, \quad (5b')$$

where $\kappa^* = f'^{-1}(r^*)$ and $\omega^* = f(\kappa^*) - \kappa^* f'(\kappa^*)$.

The government plays a very small role in this economy, since it maintains a balanced budget by using lump-sum taxes to finance an exogenously determined government spending g ; therefore, we have $q = g$.

The excess of national income over aggregate demand gives the accumulation rate of net foreign assets; in per capita terms, we have

$$\dot{b} = y + (r^* - n)b - c - \dot{k} - nk - g. \quad (6)$$

3 Dynamic properties of the model

In order to investigate the properties of stability of our economy, we may solve (4a), (4b) and (5a') -once (2) is used to eliminate l - for c , n and k in terms of λ and a :

$$c = c(\lambda), \quad c' = \frac{1}{U''} < 0; \quad (7a)$$

$$n = n(\lambda, a), \quad n_\lambda = \frac{V'}{\bar{\lambda} \Xi} < 0; \quad n_a = \frac{\bar{\lambda}}{\Xi} < 0; \quad (7b)$$

$$k = k(\lambda, a), \quad k_\lambda = \frac{\kappa^* V' T'}{\bar{\lambda} \Xi} > 0, \quad k_a = \frac{\kappa^* \bar{\lambda}}{\Xi} > 0; \quad (7c)$$

where overbars denote long-run values and $\Xi = V'' - \bar{\lambda} \omega^* T'' < 0$.

Substituting the above short-run solutions for c and n into (4c) and (6), and linearizing around the long-run equilibrium, after the expression $y =$

$r^*k + \omega^*[1 - T(n)]$ has been used, we obtain the following system of autonomous differential equations in λ and a

$$\begin{bmatrix} \dot{\lambda} \\ \dot{a} \end{bmatrix} = \begin{bmatrix} \eta_{11} & \eta_{12} \\ \eta_{21} & \eta_{22} \end{bmatrix} \begin{bmatrix} \lambda - \bar{\lambda} \\ a - \bar{a} \end{bmatrix} \quad (8)$$

where

$$\begin{aligned} \eta_{11} &= \bar{\lambda} n_\lambda < 0; & \eta_{12} &= \bar{\lambda} n_a < 0; & \eta_{21} &= -[(\bar{a} + \omega^*T')n_\lambda + c'] > 0; \\ \eta_{22} &= [\delta - (\bar{a} + \omega^*T')n_a] > 0. \end{aligned}$$

Since the economy has one jump variable, λ , and one predetermined variable, a ,⁸ saddle-point stability requires that the matrix of coefficients in (8) must have a negative determinant, since it must admit one unstable and one stable eigenvalue. Thus, for this requisite to be satisfied, it is required that

$$\Phi = \delta V'U'' + \bar{\lambda}^2 < 0. \quad (9)$$

Condition (9) is easily satisfied if $U(\cdot)$ is logarithmic and $g + \omega^*T + \delta\omega^*T' > \omega^*$.

If $\theta_1 < 0$ is the stable eigenvalue of the coefficient matrix in (8), the dynamic path of λ and a to the steady state is described by

$$a = \bar{a} + (a_0 - \bar{a})e^{\theta_1 t}, \quad (10a)$$

$$\lambda = \bar{\lambda} - \Gamma(a - \bar{a}), \quad (10b)$$

where $\Gamma = \frac{[\theta_1 + (\bar{a} + \omega^*T')n_a - \delta]}{[(\bar{a} + \omega^*T')n_\lambda + c']} > 0$. Equation (10b) represents the

⁸Although a is predetermined, k and b are free to move discontinuously since capital is costlessly mobile internationally. See Obstfeld (1989) for the same hypothesis.

unique path that converges to the long-run equilibrium.

The basic features of the dynamics for λ and a can be grasped by using the phase diagram associated with system (8), represented in Fig. 1. The locus $\dot{\lambda}=0$, which describes the combinations of λ and a at which the shadow value of wealth (hence consumption) remains constant, is downward sloping in the (λ, a) plane. The $\dot{a}=0$ locus, which shows the points at which saving vanishes, is negatively-sloped. Saddle-point stability implies that the $\dot{\lambda}=0$ locus is steeper than the $\dot{a}=0$ locus. The saddle-path SS , given by (10b), is negatively sloped and has a slope that lies in between the slopes of the $\dot{\lambda}=0$ and $\dot{a}=0$ loci.

[Insert Fig. 1]

4 Analysis of shocks

In this section, we study the consequences of two shocks: i) a reduction in δ ; and ii) an increase in g .

In order to understand how the economy works in the long-run, we underline the mechanical features of the steady state model. In the long-run, the "modified golden rule" (4c) determines population growth, i.e. $\bar{n}=r^*-\delta$. Once the time allocation constraint (2) is used, the demand for capital (5a') establishes an inverse relationship between capital stock and fertility;⁹ there-

⁹The inverse functional relationship between fertility and capital stock represents a sort of "reverse Malthus effect" (see Barro and Sala-i-Martin, 2003).

fore, from (5a'), we have: $\bar{k} = \kappa^*[1 - T(r^* - \delta)]$. Using these reduced-forms for \bar{n} and \bar{k} , the rest of the model can be condensed as follows

$$\bar{c} = \Gamma(\bar{a}, r^* - \delta), \quad \Gamma_{\bar{a}} = \frac{\bar{\lambda} \Xi}{V'U''} > 0, \quad \Gamma_{r^* - \delta} = -\frac{\bar{\lambda}^2}{V'U''} > 0, \quad (11a)$$

$$\delta \bar{a} + \omega[1 - T(r^* - \delta)] = \bar{c} + g, \quad (11b)$$

and $\bar{\lambda} = U'(\bar{c})$, and $\bar{b} = \bar{a} - \kappa^*[1 - T(r^* - \delta)]$.

Equation (11a), obtained by solving for \bar{c} the relation $\frac{V'(r^* - \delta)}{U'(\bar{c})} = \omega T'(r^* - \delta) + \bar{a}$, represents the consumption function. Consumption depends positively on nonhuman wealth and fertility, i.e. $r^* - \delta$.¹⁰ Equation (11b) states that in the steady state equilibrium the current account must be zero.

4.1 Increase in thrift

First, we analyze the steady state consequences of a decline in the rate of time preference.¹¹ A reduction in δ raises fertility because $\delta + \bar{n}$ is fixed by r^* . The higher population growth rate in turn stimulates (for a given

¹⁰Notwithstanding we are considering an immortal economy, relationship (11a) is closely resemblant to a consumption function derived from a Blanchard-Yaari "life cycle" setup (see Blanchard, 1985).

¹¹The comparative statics effects of a change in δ are given by:

$$\begin{aligned} \frac{d\bar{n}}{d\delta} &= -1 < 0; & \frac{d\bar{a}}{d\delta} &= -\frac{[\bar{\lambda} \Xi + V'U''(\bar{a} + \omega^*T')]}{\Phi} < 0; \\ \frac{d\bar{c}}{d\delta} &= -\frac{[\delta \bar{\lambda} \Xi - (\bar{a} + \omega^*T') \bar{\lambda}^2]}{\Phi} < 0; & \frac{d\bar{\lambda}}{d\delta} &= U'' \frac{d\bar{c}}{d\delta} > 0; \\ \frac{d\bar{k}}{d\delta} &= \kappa^*T' > 0; & \frac{d\bar{b}}{d\delta} &= \frac{d\bar{a}}{d\delta} - \kappa^*T' < 0; \end{aligned}$$

where $\Phi < 0$ has been defined in (9).

level of \bar{a}) consumption and, in order to keep the current account balanced, wealth. Labor hours, and hence from (5a') capital stock, are reduced because of the higher consumption of time for child-rearing. Since the rise in \bar{n} is accompanied by a decline in capital stock, the increase in wealth is entirely determined by a rise in net foreign assets. The marginal utility of wealth falls.

Domestic output is reduced, while national income is pulled up as the income earned on net foreign assets is increased. Moreover, the thriftier the economy, the higher the steady state welfare of consumers.

Consider now the dynamic adjustment of the economy when the permanent decline in δ is unexpected. As shown in Fig. 1, the new steady-state (A_1) is to the south-east of the original one (A_0). The unanticipated reduction in δ shifts the saddle-path upward.¹² The marginal utility of wealth rises on impact to bring the economy onto the new saddle-path $S'S'$ at A_{01} , experiencing a perverse-shooting of its new long-run value.

The upward jump of λ causes an instantaneous drop in the fertility rate and consumption. Capital stock jumps up in response to the fall in fertility, having assumed that real capital is instantaneously and costlessly mobile across borders, while net foreign assets fall abruptly so as to keep nonhuman wealth unchanged. Labor hours and domestic output increase on impact. Factor prices remain unchanged.

¹²In Fig. 1, it is assumed for simplicity that the slope of the saddle-path is unaffected by the shock. The vertical translation of the saddle-path, which measures the impact effect of δ on the marginal utility of wealth, is given by:

$$\frac{d\lambda(0)}{d\delta} = -\frac{\theta_1}{\bar{\lambda}(n_\lambda\delta + n_a c')} < 0.$$

After the system has been placed on the new stable arm, wealth begins to accumulate, since disposable income has been brought up on impact and consumption reduced. Consumption, fertility and net foreign assets increase along the convergent path, recovering from the initial fall, while capital and labor hours decline, overwhelming the first rise.

4.2 Increase in government spending

In the long-run, a rise in g , financed through higher lump-sum taxation, leaves fertility, capital stock and gross domestic product unchanged.¹³ Consumption, nonhuman wealth and gross national income are instead boosted. The stock of net foreign assets is increased as well. The rise in consumption reduces the marginal utility of wealth. Steady state welfare rises.

Turn now to the comparative dynamics. Suppose that the permanent rise in g is unexpected. Fig. 1 can still be used to describe the dynamic effect of this experiment. The initial equilibrium is at A_0 and the new one at A_1 . The saddle-path shifts upward after the unexpected rise in g occurs. The marginal utility of wealth suddenly rises.¹⁴ Consumption and fertility are driven down abruptly, while capital stock jumps up. Since nonhuman wealth is predetermined at its initial value, the surge of capital stock results in a net foreign asset fall.

¹³The long-run multipliers of an increase in g are given by:

$$\frac{d\bar{n}}{dg} = \frac{d\bar{k}}{dg} = 0; \quad \frac{d\bar{a}}{dg} = \frac{d\bar{b}}{dg} = \frac{V'U''}{\Phi} > 0;$$

$$\frac{d\bar{c}}{dg} = \frac{\bar{\lambda}^2}{\Phi} > 0; \quad \frac{d\bar{\lambda}}{dg} = U'' \frac{d\bar{c}}{dg} < 0.$$

¹⁴The sudden jump in the marginal utility of wealth is:

$$\frac{d\lambda(0)}{dg} = \frac{[\theta_1 n_\lambda - (n_\lambda \delta + n_a c')]}{(n_\lambda \delta + n_a c')[(\bar{a} + \omega^* T') n_\lambda + c']} > 0.$$

Once the new saddle-path has been reached, the system moves monotonically from A_{01} to A_1 with an accumulation of wealth, a rise in consumption and net foreign assets, and a reduction of the marginal utility of wealth, fertility and capital. Fertility and capital stock return to their original levels.

5 Concluding remarks

This paper has developed an intertemporal optimizing small open economy model of capital accumulation with endogenous fertility, and perfect capital mobility. We have shown that, when an endogenous population growth is incorporated into an infinite-lived economy with no adjustment costs associated with capital accumulation, the dynamics are nondegenerate as endogenous fertility choices introduce some sluggishness into the system.

The element that makes the transitional dynamics possible within such a small open economy is a demand for fertility that in the short-run depends on financial wealth. Since fertility enters the intertemporal Euler-Keynes-Ramsey condition, the dynamics of the marginal utility of wealth becomes strictly interconnected with wealth accumulation.

The dynamic behavior of the economy has been investigated for two shocks; one that changes fertility and capital formation permanently, i.e. a decline in the pure rate of time preference, and one that changes such variables only temporarily, i.e. an increase in government spending. The model exhibits saddle-point dynamics, the short-run adjustment of which is characterized by perverse-shooting.

Three final comments are in order. First, despite the fact that a model

based on endogenous fertility is similar to the corresponding model with an endogenous labor-leisure choice,¹⁵ the two models are qualitatively non-equivalent as their short and long-run behavior differs substantially. In fact, a small open economy model with elastic labor-leisure choice and no adjustment costs associated with capital accumulation exhibits degenerate dynamics, contrary to the model with endogenous fertility.¹⁶

The similarity between the two models is due to the apparently identical role of leisure and fertility. Fertility is at the same time a good as well as indirectly an input, like leisure. Differently from leisure, however, fertility enters the private budget constraint not only through the production function, but also through the term na , and, of greater importance for our purposes here, fertility enters the Keynes-Ramsey rule, rendering the dynamics of the marginal utility of wealth nondegenerate.

Second, in our small open economy we have restored saddle-point dynamics without any dependence of the steady state model on the initial conditions, as, instead, in Sen-Turnovsky (1989a and 1989b) and Mansoorian (1993). This happens because the correction of the awkward dynamics is performed through the equation that governs the evolution of the shadow value of wealth.

Third, while in the short-run the evolution of the current account mirrors that of capital formation, the two dynamics may be uncoupled along the transition path. Moreover, as fertility specularly reflects the behavior of capital stock, an association between fertility and net foreign assets emerges,

¹⁵This can be clearly seen if we re-write the model in terms of l by eliminating $n = T^{-1}(1 - l)$.

¹⁶See, for example, Turnovsky (1997, chapter 2).

which is very strong for the short-run.

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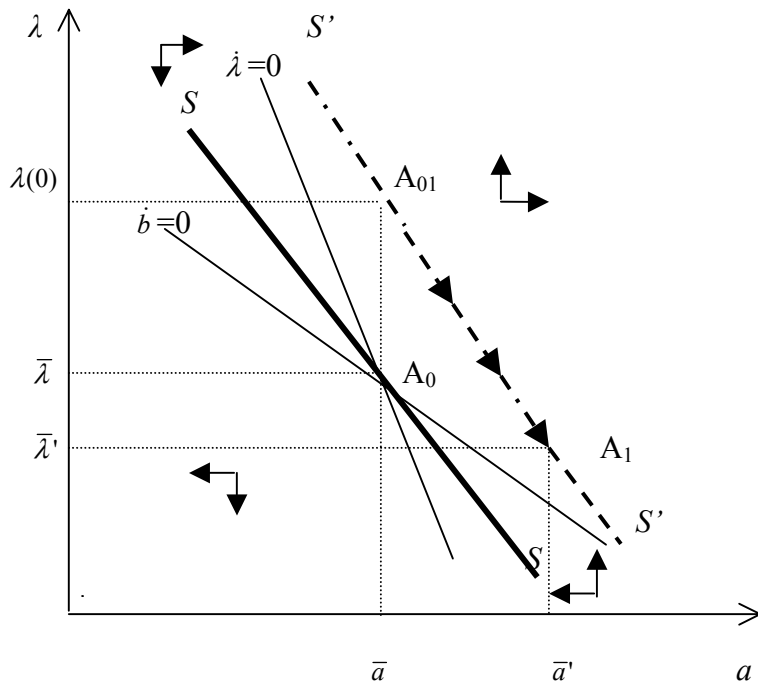


FIG. 1. Comparative Dynamics

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- (lix) This paper was presented at the ENGIME Workshop on “Mapping Diversity”, Leuven, May 16-17, 2002
- (lx) This paper was presented at the EuroConference on “Auctions and Market Design: Theory, Evidence and Applications”, organised by the Fondazione Eni Enrico Mattei, Milan, September 26-28, 2002
- (lxi) This paper was presented at the Eighth Meeting of the Coalition Theory Network organised by the GREQAM, Aix-en-Provence, France, January 24-25, 2003
- (lxii) This paper was presented at the ENGIME Workshop on “Communication across Cultures in Multicultural Cities”, The Hague, November 7-8, 2002
- (lxiii) This paper was presented at the ENGIME Workshop on “Social dynamics and conflicts in multicultural cities”, Milan, March 20-21, 2003
- (lxiv) This paper was presented at the International Conference on “Theoretical Topics in Ecological Economics”, organised by the Abdus Salam International Centre for Theoretical Physics - ICTP, the Beijer International Institute of Ecological Economics, and Fondazione Eni Enrico Mattei – FEEM Trieste, February 10-21, 2003
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- (lxvi) This paper has been presented at the 4th BioEcon Workshop on “Economic Analysis of Policies for Biodiversity Conservation” organised on behalf of the BIOECON Network by Fondazione Eni Enrico Mattei, Venice International University (VIU) and University College London (UCL), Venice, August 28-29, 2003
- (lxvii) This paper has been presented at the international conference on “Tourism and Sustainable Economic Development – Macro and Micro Economic Issues” jointly organised by CRENoS (Università di Cagliari e Sassari, Italy) and Fondazione Eni Enrico Mattei, and supported by the World Bank, Sardinia, September 19-20, 2003
- (lxviii) This paper was presented at the ENGIME Workshop on “Governance and Policies in Multicultural Cities”, Rome, June 5-6, 2003
- (lxix) This paper was presented at the Fourth EEP Plenary Workshop and EEP Conference “The Future of Climate Policy”, Cagliari, Italy, 27-28 March 2003
- (lxx) This paper was presented at the 9th Coalition Theory Workshop on "Collective Decisions and Institutional Design" organised by the Universitat Autònoma de Barcelona and held in Barcelona, Spain, January 30-31, 2004

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