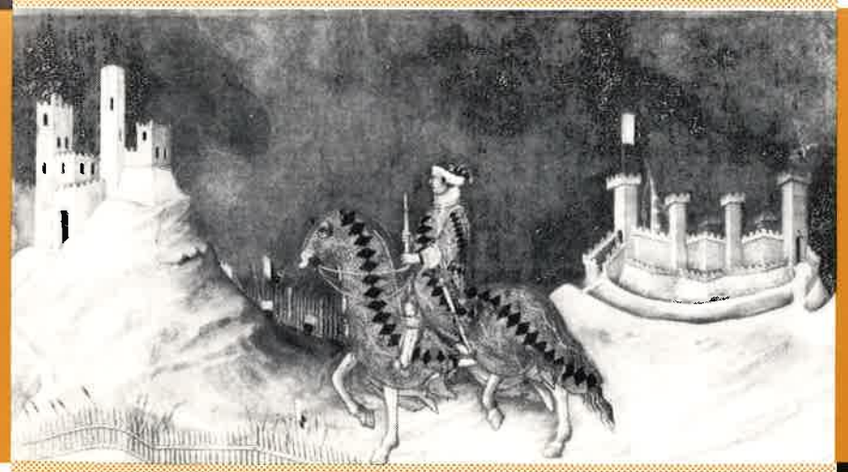
UNIVERSITÀ DEGLI STUDI DI SIENA

QUADERNI DEL DIPARTIMENTO
DI ECONOMIA POLITICA

Stefano Vannucci

A NOTE ON ERGODIC AND VMN-STABLE SETS OF ABSTRACT GAMES



QUADERNI DEL DIPARTIMENTO DI ECONOMIA POLITICA

Redazione: Dipartimento di Economia Politica, Piazza S. Francesco, 17 - 53100 Siena - tel.0577/298620

La Redazione ottempera agli obblighi previsti dall'Art.1 del D.L.L. 31.8.45 n.660

Le richieste di copie della presente pubblicazione dovranno essere indirizzate alla Redazione

I Quaderni del Dipartimento di Economia Politica dell'Università di Siena vengono pubblicati come servizio atto a favorire la tempestiva divulgazione di ricerche scientifiche originali, siano esse in forma provvisoria o definitiva. I Quaderni vengono regolarmente inviati a tutti gli istituti e dipartimenti italiani, a carattere economico, nonché a numerosi docenti e ricercatori universitari. Vengono altresì inviati ad enti e personalità italiane ed estere. L'accesso ai Quaderni è approvato dal Comitato scientifico, sentito il parere di un referee.

(Dal 1979 a tutto il 1987 la denominazione della presente Collana è stata: "Quaderni dell'Istituto di Economia". La numerazione progressiva rimane tuttavia la stessa).

Stefano Vannucci

A NOTE ON ERGODIC AND VMN-STABLE SETS OF ABSTRACT GAMES

Siena, luglio 1990

Stefano Vannucci is "Ricercatore" in the Department of Economics of the University of Siena.

1. Introduction.

The present note is devoted to the task of clarifying the relation between two different solution concepts for abstract games ,namely von Neumann-Morgenstern(vNM)- stable sets and ergodic sets.

VNM-stable sets purport to characterize those states which are robust w.r.t. theory-absorption on the part of the players. Hence,they amount to a quite sophisticated solution concept,which is in a sense an earlier game-theoretical counterpart of equilibrium concepts based on rational expectations.

By contrast,ergodic sets are meant to capture the possible "long run" outcomes of the relevant process,namely the recurrent states under a typically myopic behaviour.

Nevertheless,an underlying structural similarity among the two solution concepts has been sometimes alluded to.

In particular,Packel(1981) suggests that the ergodic solution (i.e. the join of the ergodic sets) of certain games can also be viewed as a vNM-stable set.

The aim of this note is to make precise the relation between vNM-stable sets and ergodic sets.

2. Definitions and main result.

An (exact) abstract game is a pair (X,R) . where X is an arbitrary nonempty set, called the state space, and RcXxX is a binary relation on X, the dominance relation.

We shall denote by P(R)(I(R)) the asymmetric (symmetric) component of R, and by T(R) the transitive closure of R .
Moreover,for any binary relation Bc(XxX) we shall denote by iB the inverse relation of B , and by -B the complementary relation of B (w.r.t. XxX).
A von Neumann-Morgenstern(vNM) stable set of an abstract game (X,R) is a set ScX of states enjoying the following properties:
vNM i)(internal stability) (SxS)∩R=∅ .
vNM ii)(external stability)for any x∈X\S , Sx(x)∩R≠∅ .
An absolutely stable set of (X,R) is an ScX enjoying external stability and
i')(absolute internal stability) (SxS)∩T(R)=∅.
Obviously,an absolutely stable set is a vNM-stable set as well. In fact,the notion of an absolutely stable set was introduced by Harsanyi(1974) in order to strenghten the robustness of vNM-stable sets w.r.t. to theory-absorption phenomena (as mentioned above,such robustness lies at the very foundations of vNM solution theory :see von Neumann,Morgenstern(1947) chpts.4 and 30).
The vNM-solution of a game is the set of its vNM-stable sets.
An ergodic set of an abstract game (X,R) is a nonempty set ScX of states s.t.the following conditions hold true:
E i)(persistency) ((X\S)xS)∩R=∅ .
E ii)(minimality) for any nonempty S'cX, S'cS and S'≠S entail that S' is not persistent (i.e. does not satisfy Ei)).
The ergodic solution of (X,R) is the join of its ergodic sets.
The intended meaning of an ergodic set is quite clear:it is a set of states which cannot be left,whenever reached.

However,another definition of an ergodic set has been sometimes proposed (see,for example, Packel(1981) who relabels Shenoy's "elementary dynamic solutions" (Shenoy(1979)) as "ergodic sets").
We shall see in a moment that the two proposed definitions are in fact equivalent.
Following Shenoy, we define a nontrivial(i.e.nonempty) elementary dynamic solution of the game (X,R) as a nonempty set ScX satisfying:
DS i)(pseudo-strong persistency) ((X\S)xS)∩T(R))=∅
DS ii)(communication) (SxS)cT(R) .

Proposition. Let (X,R) be an abstract game,and ScX a nonempty set of states.Then, S is persistent (i.e. satisfies E i)) iff it satisfies DS i) .
Moreover,S is an ergodic set of (X,R) iff it is an elementary dynamic solution of (X,R).

Proof. Obviously,any set ScX which satisfies DS i) satisfies E i) as well. On the other hand,let S be a persistent set of (X,R).Let us assume for a moment that S violates DS i) .
Thus,for some y∈X\S,x∈S (y,x)∈T(R).
Hence,by definition of T(R),(y',x')∈R ,for some y'∈X\S,x'∈S,a contradiction.
Let us now assume that S is an ergodic set of (X,R) which violates DS ii). Then (x,y)∉T(R) for some x,y∈S .
Let us denote by S(y) the T(R)-upper contour of y in S, i.e. S(y)={z∈S/ (z,y)∈T(R)}.
Obviously x∉S(y), whence S(y)U(y) is a proper subset of S.
Moreover, for any z∈S(y) ,w∈X\ S(y) . (w,z)∉T(R).

In fact, suppose to the contrary that (w,z)∈T(R) for some w,z as defined above. Then (w,y)∈T(R),whence w∈S(y),a contradiction.
As a consequence,S(y)U{y) is persistent as well,which in turn contradicts the minimality of S (i.e. property Eii)).
Conversely, let S be a nontrivial elementary dynamic solution of (X,R) which is not minimal persistent.
Hence,a nonempty set S'⊂S exists s.t. S'≠S and (y,x)∉R, for any y∈S\S',x∈S'. However,(y,x)∈T(R) ,by DSii). It follows that y'∈S\S',x'∈S' exist s.t. (y',x')∈ R, by definition of T(R) and DS i) : a contradiction. ∎

Remark 1.The foregoing proposition makes it crystal clear that the ergodic sets of a given game are pairwise disjoint.

Remark 2.In a remarkable paper,Kalai,Schmeidler(1977) prove that the ergodic solution E of an abstract game (X,R)(i.e. the join of its ergodic sets, which they call the "admissible set") is characterized by the following condition:
(admissibility):((XxE)∩T(R)⊂(XxE)∩i(T(R)).
It follows that,whenever a game has a unique ergodic set,"admissibility","persistency plus minimality" and "persistency plus communication" turn out to be three equivalent sets of restrictions over the power set of X.
More complex alternative characterizations of the ergodic solution of a game are offered in Schwartz(1972)(who works with a finite asymmetric (X,R)) and in Kim,Roush(1979).

The following general relation between vNM-stable sets and ergodic sets holds true.

Theorem. Let (X,R) be an abstract game s.t. (X,T(R)) is connected. Then ,the following statements are equivalent:
i) AcX is an ergodic set of (X,R);
ii)AcX is a vNM-stable set of (X,P(T(R)));
iii)AcX is an absolutely stable set of (X,P(T(R))).

Proof.Let A be an ergodic set of (X,R). Thus,for any x,y∈A, (x,y)∈T(R) and (y,x)∈T(R),by DSii) and the foregoing proposition. Therefore,(x,y)∉P(T(R)) whence the internal stability of A follows.Notice:since T(R) is transitive, P(T(R)) is transitive as well. Thus,T(P(T(R)))=P(T(R)).As a result, A turns out to enjoy absolute internal stability w.r.t.(X,P(T(R))).
Let us now consider any ordered pair (y,x)∈((X\A)xA) . Obviously, (y,x)∉T(R) (by E i)).Hence ,by connectedness, (x,y)∈T(R). Therefore (x,y)∈P(T(R)),which entails external stability.
Conversely,let A be a vNM-stable set of (X,P(T(R)))(hence an absolutely stable set as well, in view of P(T(R))'s transitivity). Obviously, A is nonempty,by external stability.
Moreover,for any x∈A,y∉A (y,x)∈T(R) implies (z,x)∈P(T(R)) for some z∈A,by external stability of A and transitivity of T(R):a contradiction.Hence A is persistent .
The proof that A satisfies minimality (E ii) is by contradiction as well. Let us assume that a set B⊂X exists s.t.it is both a proper subset of A and an ergodic set of (X,R).
Let us now consider two states x∈A\B,y∈B . It follows that (x,y)∉T(R) by persistency (Ei)) of B.

On the other hand ,internal stability of A entails (y,x)∉P(T(R)),whence (y,x)∉T(R),a contradiction. Q.E.D. ▌

Remark 3.It should be clear from the foregoing theorem that an ergodic set A of (X,R) with connected T(R) turns out to be the (nonempty) core of (X,P(T(R))) which is in fact the unique vNM-stable set of (X,P(T(R))).It follows that under the hypothesis of our theorem (X,R) has at most one ergodic set, which - if it exists - is the same as the whole ergodic solution.
It is left to the reader as a simple exercise to check that A is indeed admissible.
Also, if (X,R) is an (asymmetric) strict total ordering then a set AcX of states is an ergodic set iff it is an absolutely stable set (or,equivalently, a vNM-stable set) of (X,R) ,i.e. the three solutions concepts -as should be expected- coincide.
Furthermore,let us call a game chaotic w.r.t. a given solution concept whenever its corresponding solution is the whole state space.
Then, the theorem implies that (X,R) is ergodically chaotic iff (X,P(T(R))) is vNM- chaotic ,provided that T(R) is connected (see McKelvey(1979) for a fairly general chaos theorem).

The following example makes it clear that the theorem does not hold true if T(R) is not connected:

Example 1.Let X={x,y,z,w,u,t},R={(x,y),(y,z),(z,w),(u,t)}. {x,z,u} is an absolutely stable set of (X,P(T(R))).However, the ergodic sets of (X,T(R)) are {x} and {u} (hence {x,u} is the ergodic solution of (X,T(R)),and x,u are in fact

absorbant states :see Roberts(1976),or Berge(1979)for a detailed presentation of such graph-theoretic concepts).

Also,replacing P(T(R)) with a connected T(R),or even with a connected R turns the theorem into an invalid statement,as the following example shows:

Example 2. Let X={x,y,z,w },R'={(x,y),(y,z),(z,w),(w,x)}.Of course, T(R') is connected. On the other hand, X is the only ergodic set (hence the ergodic solution) of (X,R') and (X,T(R')):in graph-theoretic terminology the state space X is ,in both cases,irreducible (in game-theoretical terminology,the game is ergodically chaotic).However,neither (X,R') nor (X,T(R')) possess any vNM-stable set.

As a straightforward consequence of the theorem proved above and of previous results due to Kalai and Schmeidler one gets the following existence and uniqueness results for (absolutely) vNM-stable sets:

Corollary .Let (X,R) be s.t. X is a nonempty compact topological space and T(R) is connected.
Then the following statements hold true:
i)if the lower contours of R (i.e. the sets {y∈X/(x,y)∈R} , for any x∈X)are open , then (X,P(T(R))) has a unique vNM-stable set (which is in fact an absolutely stable set as well): namely, the ergodic set of (X,R).
ii) if the upper contours of T(R) are closed ,then (X,P(T(R))) has an unique vNM-stable(and absolutely stable) set,namely the ergodic set of (X,T(R)).

Proof.i) It follows from theorem 2 in Kalai,Schmeidler(1977) and the theorem above.
ii) It follows from theorem 3 in Kalai,Schmeidler(1977) and the theorem above. ▌

Remark 4.The foregoing existence results are indeed general enough to deserve mention, since it is well known that vNM-stable sets may not exist (see Lucas(1977)).
The uniqueness results are perhaps even more relevant. This is so because multiplicity of vNM-stable sets is in fact a quite common occurrence.
On the other hand , uniqueness enhances considerably the plausibility of a vNM-stable set as a solution.
Obviously ,a similar claim may be made for any solution concept.
However,uniqueness of vNM-stable sets is a highly valuable property on a more "intrinsic" ground,namely theory-absorption. In fact, a unique vNM-stable set is more robust w.r.t. theory-absorption in that it entails lack of possible ambiguities about the relevant vNM-stable set or "standard of behaviour":it enjoys the "solidity" requirement, according to the terminology of Forman,Laing(1982), which is not the case for multiple vNM-stable sets.
It should also be mentioned here that any finite (X,R) has an ergodic solution (see Schwartz(1972) Kalai,Pazner, Schmeidler (1976), and Kalai,Schmeidler(1977), theorem 1).
As a consequence , whenever (X,T(R)) is finite and connected a set of states AcX exists s.t.:a)A is the unique ergodic set of (X,R);b)A is the core of (X,P(T(R)));c)A is the unique vNM-stable set of (X,P(T(R)));d)A is the unique absolutely stable set of (X,P(T(R))).

3.Concluding remarks.
It is worth stressing again the striking difference between the arguments which motivate the use of vNM-stable sets and ergodic sets,respectively, as a sensible solution concept.
The classical argument advanced by von Neumann and Morgenstern is a paradigm of game-theoretic reasoning.
The von Neumann-Morgenstern line of reasoning may be described as follows: whenever the players know the game they are playing and learn that vNM-stable sets are the relevant solution concept,each state belonging to a vNM-stable set is in a sense "hard to leave".In fact,it turns out that any state z which happens to dominate x cannot be a real threat. This is so because such a state cannot belong to the above mentioned vNM-stable set ,by internal stability:hence,whenever implemented it would be replaced by another state y of the given vNM-stable set. However,no coalition effectively supports y against x,including of course those coalitions which could effectively support the move from x to z.It follows that the relevant coalitions lack any positive incentive to implement such a move from x to z, provided that the coalitions which can force z against x can also force y against x.
On the other hand,a state z which does not belong to a given vNM-stable set S is "easy to leave",since it is exposed to an effective threat by a state of S,which in turn cannot be threatened,by the reasoning presented in the foregoing paragraph.
Thus,for each single state which belongs to a vNM-stable set some "stability claim"- if admittedly supported by the whole set - is in fact implied(see von Neumann,Morgenstern(1947)

for the original definition of stable sets;see also Lucas(1977), Lucas,Michaelis(1982),Schmidt,Strohlein(1985) Berge(1979) for critical surveys of problems ,ideas and results concerning vNM-stable sets, and Harsanyi(1974), Roth(1976), Forman,Laing(1982) for some interesting attempts to improve and/or generalize the original von Neumann-Morgenstern's argument reported above).

Let us now turn to ergodic sets and solutions.

As a matter of fact,the ideas underlying ergodic sets are not game-theoretic in origin.Rather,they arise from Markov chains and graph theory.

Versions of ergodic sets,under various labels,were introduced in social choice and game theory in the'70s to support transitive closure-maximizing social choice functions (see Schwartz(1972),Kalai,Pazner,Schmeidler(1976), Deb(1977),;see also Campbell(1980),Bordes(1983), and Moulin(1986)for a recent comprehensive treatment of this subject and related matters for the tournament case),and to analyze coalition formation processes(see Shenoy(1979)).

Ergodic solutions have also been shown to provide a general structure which easily specializes to various cooperative and noncooperative game-theoretical solution concepts(see Kalai,Schmeidler(1977);see also Greenberg(1989) for an application of vNM-stable sets in a very similar vein).

As mentioned above,ergodic sets are tailored to capture a sort of "long run" stability under a somewhat myopic behaviour. In particular,no attention is paid to the effects of theory-absorption on the part of the players.Also,no stability claim is implied for the single elements of an ergodic set. In fact,the suggested refinements of the ergodic solution concept typically amount to a (stationary)probability distribution on the set of

states,s.t. its support is the ergodic solution itself(see Packel(1981), Ferejohn,McKelvey,Packel(1984)).

The result presented in this note entails that,in spite of those striking differences w.r.t. theoretical background and motivation,ergodic and vNM solutions entertain a remarkably strict relation under connectedness of the indirect dominance relation.

References

BERGE C.(1979):Graphs and Hypergraphs. North Holland , Amsterdam.

BORDES G.A.(1983):On the Possibility of Reasonable Consistent Majoritarian Choice:Some Positive Results.Journal of Economic Theory 31,122-132.

CAMPBELL D.E.(1980):Algorithms for Social Choice Functions. Review of Economic Studies 47,617-627.

DEB R.(1977):On Schwartz's Rule. Journal of Economic Theory 16,103-110.

FEREJOHN J.A.,R.D.McKELVEY, E.W.PACKEL(1984) :Limiting Distributions for Continuous State Markov Voting Models. Social Choice and Welfare 1,45-67.

FORMAN R.,J.D.LAING (1982):Metastability and Solid Solutions of Collective Decisions. Mathematical Social Sciences 2,397-420.

GREENBERG J.(1989):Deriving Strong and Coalition-Proof Nash Equilibria from an Abstract System. Journal of Economic Theory 49,195-202.

HARSANYI J.C.(1974):An Equilibrium-Point Interpretation of Stable Sets and a Proposed Alternative Definition.. Management Science 20,1472-1495.

KALAI E.,E.PAZNER,D.SCHMEIDLER (1976):Collective Choice Correspondences as Admissible Outcomes of Social Bargaining Processes. Econometrica 44,233-240.

KALAI E.,D.SCHMEIDLER (1977):An Admissible Set Occurring in Various Bargaining Situations. Journal of Economic Theory 14,402-411.

KIM K.H.,F.W.ROUSH (1979):Characterization of Certain Choice Functions. Journal of Economic Theory 20,271-275.

LUCAS W.F.(1977):The Existence Problem for Solutions,in R.Henn,O.Moeschlin(eds.):Mathematical Economics and Game Theory.Springer-Verlag ,Berlin,64-75.

LUCAS W.F.,K.MICHAELIS (1982):Finite Solution Theory for Coalitional Games. S.I.A.M. Journal of Algebraic and Discrete Methods 3,551-565.

McKELVEY R.D.(1979):General Conditions for Global Intransitivities in Formal Voting Models. Econometrica 47,1085-1112.

MOULIN H. (1986):Choosing from a Tournament. Social Choice and Welfare 3,271-291.

PACKEL E.W.(1981):A Stochastic Solution Concept for n-Person Games. Mathematics of Operations Research 6,349-362.

ROBERTS F.S.(1976):Discrete Mathematical Models . Prentice-Hall, Englewood Cliffs N.J. .

ROTH A.E.(1976):Subsolutions and the Supercore of Cooperative Games. Mathematics of Operations Research 1,43-49.

SCHMIDT G.,T.STROHLEIN (1985):On Kernels of Graphs and Solutions of Games:A Synopsis Based on Relations and Fixpoints. S.I.A.M. Journal of Algebraic and Discrete Methods 6,54-65.

SCHWARTZ T.(1972):Rationality and the Myth of the Maximum. Nous 6,97-117.

SHENOY P.P.(1979):On Coalition Formation:A Game-Theoretical Approach. International Journal of Game Theory 8,133-164.

VON NEUMANN J.,O.MORGENSTERN (1947):Theory of Games and Economic Behavior. Princeton University Press.Princeton N.J.(2nd edition).

Elenco dei Quaderni pubblicati

n.1 (febbraio 1979) MASSIMO DI MATTEO, Alcune considerazioni sui concetti di lavoro produttivo e improduttivo in Marx
n.2 (marzo 1979) MARIA L.RUIZ, Mercati oligopolistici e scambi internazionali di manufatti. Alcune ipotesi e un'applicazione all'Italia
n.3 (maggio 1979) DOMENICO MARIO NUTI, Le contraddizioni delle economie socialiste: una interpretazione marxista
n.4 (giugno 1979) ALESSANDRO VERCELLI, Equilibrio e dinamica del sistema economico-semantica dei linguaggi formalizzati e modello keynesiano
n.5 (settembre 1979) A. RONCAGLIA - M. TONVERONACHI, Monetaristi e neokeynesiani: due scuole o una?
n.6 (dicembre 1979) NERI SALVADORI, Mutamento dei metodi di produzione e produzione congiunta
n.7 (gennaio 1980) GIUSEPPE DELLA TORRE, La struttura del sistema finanziario italiano: considerazioni in margine ad un'indagine sull'evoluzione quantitativa nel dopoguerra (1948-1978).
n.8 (gennaio 1980) AGOSTINO D'ERCOLE, Ruolo della moneta ed impostazione antiquantitativa in Marx: una nota
n.9 (novembre 1980) GIULIO CIFARELLI, The natural rate of unemployment with rational expectations hypothesis. Some problems of estimation
n.10 (dicembre 1980) SILVANO VICARELLI, Note su ammortamenti, rimpiazzi e tasso di crescita
n.10 bis (aprile 1981) LIONELLO F. PUNZO, Does the standard system exist?
n.11 (marzo 1982) SANDRO GRONCHI, A meaningful sufficient condition for the uniqueness of the internal rate of return
n.12 (giugno 1982) FABIO PETRI, Some implications of money creation in a growing economy
n.13 (settembre 1982) RUGGERO PALADINI, Da Cournot all'oligopolio: aspetti dei processi concorrenziali
n.14 (ottobre 1982) SANDRO GRONCHI, A Generalized internal rate of return depending on the cost of capital
n.15 (novembre 1982) FABIO PETRI, The Patinkin controversy revisited
n.16 (dicembre 1982) MARINELLA TERRASI BALESTRIERI, La dinamica della localizzazione industriale: aspetti teorici e analisi empirica
n.17 (gennaio 1983) FABIO PETRI, The connection between Say's law and the theory of the rate of interest in Ricardo
n.18 (gennaio 1983) GIULIO CIFARELLI, Inflation and output in Italy: a rational expectations interpretation
n.19 (gennaio 1983) MASSIMO DI MATTEO, Monetary conditions in a classical growth cycle
n.20 (marzo 1983) M. DI MATTEO - M.L. RUIZ, Effetti dell'interdipendenza tra paesi produttori di petrolio e paesi industrializzati: un'analisi macrodinamica
n.21 (marzo 1983) ANTONIO CRISTOFARO, La base imponibile dell'IRPEF: un'analisi empirica
n.22 (gennaio 1984) FLAVIO CASPRINI, L'efficienza del mercato dei cambi. Analisi teorica e verifica empirica
n.23 (febbraio 1984) PIETRO PUCCINELLI, Imprese e mercato nelle economie socialiste: due approcci alternativi

n.24 (febbraio 1984) BRUNO MICONI, Potere prezzi e distribuzione in economie mercantili caratterizzate da diverse relazioni sociali
n.25 (aprile 1984) SANDRO GRONCHI, On investment criteria based on the internal rate of return
n.26 (maggio 1984) SANDRO GRONCHI, On Karmel's criterion for optimal truncation
n.27 (giugno 1984) SANDRO GRONCHI, On truncation "theorems"
n.28 (ottobre 1984) LIONELLO F. PUNZO, La matematica di Sraffa
n.29 (dicembre 1984) ANTONELLA STIRATI, Women's work in economic development process
n.30 (gennaio 1985) GIULIO CIFARELLI, The natural rate of unemployment and rational expectation hypotheses: some empirical tests
n.31 (gennaio 1985) SIMONETTA BOTARELLI, Alcuni aspetti della concentrazione dei redditi nel Comune di Siena
n.32 (febbraio 1985) FOSCO GIOVANNONI, Alcune considerazioni metodologiche sulla riforma di un sistema tributario
n.33 (febbraio 1985) SIMONETTA BOTARELLI, Ineguaglianza dei redditi personali a livello comunale
n.34 (marzo 1985) IAN STEEDMAN, Produced inputs and tax incidence theory
n.35 (aprile 1985) RICHARD GOODWIN, Prelude to a reconstruction of economic theory. A critique of Sraffa
n.36 (aprile 1985) MICHIO MORISHIMA, Classical, neoclassical and Keynesian in the Leontief world
n.37 (aprile 1985) SECONDO TARDITI, Analisi delle politiche settoriali: prezzi e redditi nel settore agroalimentare
n.38 (maggio 1985) PIETRO BOD, Sui punti fissi di applicazioni isotoniche
n.39 (giugno 1985) STEFANO VANNUCCI, Schemi di gioco simmetrici e stabili e teoremi di possibilità per scelte collettive
n.40 (luglio 1985) RICHARD GOODWIN, The use of gradient dynamics in linear general disequilibrium theory
n.41 (agosto 1985) M. MORISHIMA and T. SAWA, Expectations and the life span of the regime.
n.42 (settembre 1985) ALESSANDRO VERCELLI, Keynes, Schumpeter, Marx and the structural instability of capitalism
n.43 (ottobre 1985) ALESSANDRO VERCELLI, Money and production in Schumpeter and Keynes: two dichotomies
n.44 (novembre 1985) MARCO LONZI, Aspetti matematici nella ricerca di condizioni di unicità per il Tasso Interno di Rendimento
n.45 (dicembre 1985) NIKOLAUS K.A. LAUFER, Theoretical foundations of a new money supply hypothesis for the FRG.
n.46 (gennaio 1986) ENRICO ZAGHINI, Una dimostrazione alternativa dell'esistenza di equilibri in un modello di accumulazione pura
n.47 (febbraio 1986) ALESSANDRO VERCELLI, Structural stability and the epistemology of change: a critical appraisal
n.48 (marzo 1986) JOHN HICKS, Rational behaviour: observation or assumption?
n.49 (aprile 1986) DOMENICO MARIO NUTI, Merger conditions and the measurement of disequilibrium in labour-managed economies
n.50 (maggio 1986) SUSAN SENIOR NELLO, Un'applicazione della Public Choise Theory alla questione della riforma della Politica Agricola Comune della CEE
n.51 (maggio 1986) SERENA SORDI, Some notes on the second version of Kalecki's Business Cycle Theory
n.52 (giugno 1986) PIERANGELO GAREGNANI, The classical theory of wage and the role of demand schedules in the determination of relative prices
n.53 (luglio 1986) FRANCO BIRARDI, Crescita, sviluppo ed evoluzione: l'affermazione dei nessi strutturali sistematici e la combinazione di scienza, tecnologia ed economica nelle prime industrializzazioni
n.54 (agosto 1986) M. AMENDOLA - J.L. GAFFARD, Innovation as creation of technology: a sequential model
n.55 (settembre 1986) GIULIO CIFARELLI, Exchange rates, market efficiency and "news". Model specification and econometric identification
n.56 (settembre 1986) ALESSANDRO VERCELLI, Technological flexibility, financial fragility and the recent revival of Schumpeterian entrepreneurship
n.57 (ottobre 1986) FABIO PETRI, The meaning of the Cambridge controversies on capital theory: an attempt at communication
n.58 (ottobre 1986) DANIELE CHECCHI, The international coordination of counter-cyclical policies
n.59 (novembre 1986) ALESSANDRO VERCELLI, Probabilistic causality and economic models: Suppes, Keynes, Granger
n.60 (dicembre 1986) LIONELLO F. PUNZO, J. Von Neumann and K. Menger's mathematical colloquium
n.61 (dicembre 1986) MICHAEL BACHARACH, Three scenarios for fulfilled expectations
n.62 (gennaio 1987) J. ESTEBAN and T. MILLAN, Competitive equilibria and the core of overlapping generations economies
n.63 (gennaio 1987) ROBERT W. CLOWER, New directions for keynesian economics
n.64 (febbraio 1987) MARCO P. TUCCI, A simple introduction to flexible functional forms and consumer behaviour theory
n.65 (marzo 1987) NICOLA DIMITRI, Generalizations of some continuos time epidemic models
n.66 (aprile 1987) MASSIMO DI MATTEO, Goodwin and the Evolution of a Capitalistic Economy: An Afterthought
n.67 (maggio 1987) MASSIMO DI MATTEO, Early Discussions on Long Waves
n.68 (giugno 1987) MASSIMO DI MATTEO, Warranted, Natural, and Actual Rates of Growth: Reflections of a Perplex
n.69 (settembre 1987) LUISA MONTUSCHI, Inward-Looking development and import substitution in the Argentine Economy 1950-1980
n.70 (dicembre 1987) GIANCARLO GANDOLFO and PIETRO CARLO PADOAN, The Mark V version of the Italian continuos time model
n.71 (dicembre 1987) SILVANO VICARELLI, Impatience to consume, the utility of wealth and the rate of interest
n.72 (gennaio 1988) OMAR CHISARI, Worker's assets, foreign debt and the dynamics of an economy
n.73 (febbraio 1988) STEFANO VANNUCCI, On exactly strong-Nash-implementable power allocations
n.74 (marzo 1988) PIER LUIGI LANDI, Aspetti economici della società anonima della strada ferrata Empoli-Siena o Centrale Toscana fino al 1859
n.75 (aprile 1988) FRANCO BIRARDI, Generating the space of physical characteristics by means of elements which are discrete and limited over time (A note on innovation in chemical technologies)
n.76 (maggio 1988) LILIA COSTABILE, Politica monetaria, debito pubblico e tasso di interesse

n.77 (giugno 1988) GIUSEPPE DELLA TORRE, L'evoluzione dei sistemi finanziari nell'approccio contabile di Raymond Goldsmith. Alcune considerazioni analitiche
n.78 (luglio 1988) FRANCESCO FARINA, Fattori tecnologici e transazionali nella divisione interindustriale del lavoro
n.79 (ottobre 1988) FRANCESCO FARINA, Gli obiettivi della Banca d'Italia e i tassi d'interesse sul debito pubblico
n.80 (novembre 1988) GIULIO CIFARELLI, La razionalità del tasso di cambio a termine e le "notizie": una analisi empirica
n.81 (dicembre 1988) MAURO CAMINATI, Cyclical growth in a long-period perspective
n.82 (gennaio 1989) LUIGI LUINI, Crescita esterna dell'impresa e teorie economiche
n.83 (marzo 1989) LUIGI M. TOMASINI, A Scheme to Allocate Wastewater Rights
n.84 (aprile 1989) STEFANO VANNUCCI, On Consistency Properties of some Strongly Implementable Social Choice Rules with Endogenous Agenda Formation
n.85 (maggio 1989) AGOSTINO D'ERCOLE, Economia e Moneta in Schumpeter
n.86 (maggio 1989) CHARLES GOODHART, What do Central Banks Do?
n.87 (giugno 1989) PAOLO DEL GIOVANE, Foreign Firms' Behavior in the United States Market during the Dollar Cycle
n.88 (giugno 1989) GÉRARD DUMÉNIL and DOMINIQUE LÉVY, The classical legacy and beyond
n.89 (luglio 1989) RICCARDO FIORITO, Inventory accounting and profit evaluation
n.90 (settembre 1989) NICOLA DIMITRI, On the robustness of the rational expectations hypothesis
n.91 (settembre 1989) PIERMARIO PACINI, Expectations, learning and equilibrium in a non-walrasian model: a constructive approach
n.92 (ottobre 1989) AGOSTINO D'ERCOLE, Sulla teoria monetaria del tasso di interesse di Schumpeter
n.93 (ottobre 1989) UGO PAGANO, Firms, co-ordination and disequilibrium
n.94 (novembre 1989) UGO PAGANO, Determinazione endogena dei diritti di proprietà in una economia di mercato
n.95 (dicembre 1989) UGO PAGANO, Property rights, asset specificity, and the division of labour under alternative capitalist relations
n.96 (dicembre 1989) MICHIO MORISHIMA, Wage differentials in Japan: 1958-1985
n.97 (gennaio 1990) PIERPAOLO PIERANI - PIER LUIGI RIZZI, An econometric analysis of the olive oil market in Italy
n.98 (febbraio 1990) ENRICO GIOVANNINI, Squilibri settoriali e dinamica macroeconomica di breve periodo: il caso dell'industria italiana
n.99 (maggio 1990) GIULIO CIFARELLI Sui determinanti degli errori di previsione a termine nel mercato dei cambi
n.100 (maggio 1990) EDITED BY MASSIMO DI MATTEO Celebrating R.M. Goodwin's 75 birthday
n.101 (maggio 1990) OMAR O. CHISARI - JOSE' M. FANELLI Three-gap models, optimal growth and the economic dynamics of highly indebted countries
n.102 (giugno 1990) FRANCESCO FARINA Italy's monetary policy inside the european monetary system
n.103 (giugno 1990) STEFANO VANNUCCI On the closure operators of an effectivity function
n.104 (giugno 1990) STEFANO VANNUCCI Struttura del mercato, giochi semplici e potenziali monopolistici

Alla presente Collana "gialla" di quaderni il Dipartimento di Economia Politica affianca una Collana "celeste" di monografie. I numeri pubblicati a tutt'oggi sono i seguenti:

1) GIUSEPPE DELLA TORRE, Istituzioni creditizie ed Accumulazione del Capitale in Italia (1948-81), 1984.

2) SANDRO GRONCHI, Tasso Interno di Rendimento e Valutazione dei Progetti: una Analisi Teorica, 1984.

3) ALDINO MONTI, La Proprietà Immobiliare a Bologna in Età Napoleonica (1797-1810), 1984.

4) GIULIO CIFARELLI, Equilibrium and Disequilibrium Interpretations of Inflation, 1985.