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12 December 2013

Causality and interdependence in Pasinetti's works and in the modern classical approach

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One of the items that Pasinetti rightfully emphasizes in characterizing the Cambridge school, and differentiating it from mainstream neoclassicism is causality versus interdependence. (Leijonhufvud, 2008, 537)

Abstract. The formal representation of economic theories normally takes the form of a model, that is, a system of equations which connect the endogenous variables with the values of the parameters which are taken as given. Sometimes, it is possible to identify one or more equations which are able to determine a subset of endogenous variables priorly and independently of the other equations and of the value taken by the remaining variables of the system. The first group of equations and variables are thus said to determine *causally* the remaining variables. In Pasinetti's works this notion of causality has often been emphasized as a formal property having the burden to convey some deep economic meaning. In this work, we will go through those Pasinetti's works where this notion of causality plays a central role, with the purpose to contextualize it within the econometric debate of the Sixties, to enucleate its economic meaning and to show its connections with other fields of the modern classical approach.

Preliminary version; English to be revised

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(12/12/2013)

J.E.L. **classification**: B00, B24, B51, C50, E12.

Keywords: causality, interdependence, modern classical approach, Ricardo theory distribution, Keynes' analysis, 'given quantities', surplus approach, structural dynamics, vertical integration.

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* Previous versions of this paper have been presented in four conferences: AISPE (Associazione Italiana per la Storia del Pensiero Economico – Firenze, 2013), STOREP (Associazione Italiana per la Storia dell'Economia politica – Gaeta, 2013), AHE (Association for Heterodox Economics – London, 2013) and Structural Change, Dynamics, and Economic Growth (Livorno, 2013). We thank Daniela Parisi and Andrea Salanti for criticisms and comments on a previous version of the work. This research has been partially supported by a grant erogated by the Italian Ministry of University and Research (MIUR, PRIN 2009, grant 2009NXTCP9_006), which is gratefully acknowledged.

1. Introduction

All along his career Luigi L. Pasinetti has been working on a titanic confrontation between two opposing paradigms: the Classical-Keynesian and the Marginalist or Neoclassical one. Among the major differences which mark the distance between the two there is, in his view, the importance and the role they attach, respectively, to the principles of causation and interdependence in economic theorizing.

During the 1970s and 1980s a vivid debate arose on the meaning and the significance of the concepts of causality and interdependence in economic theory: those very concepts came to be dissected along many different perspectives and to be somewhat intermingled, so that the area of disagreement widened without providing grounds for a clarification of the different positions (Cavalieri, 1987-1988; Vercelli, 1991). This dispute had clear connections with the ongoing developments in econometrics: the spreading application of VAR and later SVAR techniques revived the discussion between (and within) the supporters of a structural approach to econometrics, grounded on the building up of structural models representing a set of allegedly stable economic behaviors, and the process approach, basically rejecting any a-priori assumption and focusing exclusively on the multiple correlations emerging from historical time-series of economic data (Hoover, 2008, p. 724; Cellini, 1995, p. 343; Drakopoulos and Torrance 1994, p. 186-187)[1]. More generally the debate over causality in economics and econometrics involved deep epistemic issues concerning the meaning of causality, which recursively resumed a deterministic stance, both in the theoretical and probabilistic analyses (Vercelli, 2001, p 1; Drakopoulos and Torrance, 1994; Cavalieri, 2000).

Pasinetti's own interest on the notion of causality dated back to his graduation studies at the Catholic University of Milan, under the tutorship of Francesco Vito, Giancarlo Mazzocchi and the young Siro Lombardini. Especially the latter introduced Pasinetti to the study of econometrics and encouraged him to devote his dissertation and his first research papers to the study of consumption and investment functions in econometric models (Pasinetti, 1955, 1957a, 1956). In 1957-58, in the middle of his PhD studies in Cambridge (UK) and Oxford, he spent one year in Harvard, attending Franco Modigliani's courses. In 1964 Pasinetti was appointed professor to the newly created chair of econometrics at the Catholic University[2].

Yet, since the end of 1950s, Pasinetti's interest in causal economic relations was driven more by theoretical reflection than by empirical verification or econometric modeling. The encountering with the Cambridge school, spurred his attention to the different methodological approaches that differentiated the classical and, later, Keynesian economists from neoclassical ones and from the younger generation of

[1] On the history of econometrics see Epstein (1987), De Marchi and Gilbert (2001), Morgan (1990), Qui (1993).

[2] On Pasinetti's training as an economist see Parisi (2013), Quadrio Curzio and Rotondi (2004, p.402-405).

Keynesians (not yet labeled "bastard") whose growing influence on modern macroeconomics and policy making was couched in the form of a reconciliation of Keynes with Walrasian general equilibrium analysis. Pasinetti's own desire to qualify the differences between those streams of thought, not yet openly fighting each other, led him to specify their different visions of economic theory. In his view, the classical and Keynesian traditions were grounded on the identification of fundamental causal relationship, in which some of the forces under inquiry played the role of *primum movens*, able to set in motion and determine the pace and the direction of economic change: the rate of profit in the Ricardian model (1960); the principle of effective demand in the Keynes' General Theory (1974)[3]; capitalist's saving decisions in Kaldor's theory of growth and income distribution (1962 and 1974); technology and consumption patterns in his own *Structural change and economic dynamics (1981; 1993)*.

Pasinetti's attention on the notion of causality has never faded away: the development of a strong notion of causality (and time dependence with it) is still regarded, in his own words, as one of the major challenges economic theorizing should address today in order to recover his own role among the social sciences and help providing answers to the most pressing social issues of our time, such as unemployment, technical change, income distribution.

> The notion of historical time opens up the question of causality. ... There are relations, in economics, that are genuinely interdependent. But there are other important economic relations that are characteristically asymmetrical, as far as the chain of causality is concerned. They should not be artificially forced into a logical frame in which everything depends on everything else, which is tantamount to introducing an unjustified sharp distinction which considers any specific variable as *either* totally unimportant (and in this case to be neglected) *or* of some importance and in this case to be considered exactly on the same level as, and symmetrically to, any one of the other variables, no matter how important these latter variables may be relative to the former (Pasinetti, 2007, p. 226).

In this paper we shall try to trace out the origins of Pasinetti's notion of causality (Section 2) and describe how it was developed in his major works. We will especially focus upon his famous reformulation of the Ricardian system (Section 3), his view of Keynes' contribution vs. Hicks' neoclassical synthesis (Section 4), and his analysis of structural change (Section 5). Section 6 concludes.

2. Pasinetti's reflection on causality

Pasinetti's interest in the relationship between causality and interdependence in economics was deeply rooted in its own training as econometrician under the guide of Siro Lombardini. Since the late 1940s, Lombardini had been an acute observer of the rapid advancements occurring in econometrics: a two years fellowship in the United States allowed him to follow the works of the Cowles Commission and acquire a wide knowledge of the main technical and methodological issues involved in econometric modeling (Lombardini, 1952, p. 409). In the 1905s Lombardini continued to take part in

[3] On Keynes' concept of causality see Carabelli (1983) and (1988), Vercelli (1991).

the conferences of the Econometric Society and assessed the pros and cons of the different positions emerging in the debate (Lombardini, 1955, p. 1957)[4].

Two major approaches were facing each other at the time: the Cowles commission approach, that geared around the "structural" econometric models, based on the identification of exogenous and endogenous variables, within a system of simultaneous equations; the second (minority) approach, developed by Herman Wold and the Swedish school, that was based on "process" analysis, with causal relationships and time dependence as their basic features and with no a-priori distinction between endogenous or exogenous variables (Lombardini, 1955, p. 304-309; Hoover, p. 2008: 721).

A third solution was proposed by Herbert Simon in a famous 1953 article on "Causal ordering and identifiability" in which, in the context of structural models, he defined causality as an asymmetric or "recursive" relationship between variables (not necessarily sequential in time), taking care of distinguishing the positivistic, ontological and deterministic notion of causality from a more acceptable logical notion, related to the formal property of a model (Hoover, 2008, p. 721; Lombardini, 1955, p. 309).

It was Lombardini who encouraged Pasinetti to devote his graduation dissertation to a deep and detailed discussion of the main econometric models of business cycles elaborated at the time by Jan Timbergen (1939), Colin Clark (1949), Lawrence Klein (1950) and built upon the newly available data of the American economy in the interwar years: the estimation of the consumption and investment functions was also the specific focus of Pasinetti's earlier published articles (1955 and 1957a), in which he made an attempt to improve the former models with the new theories of consumption developed by Franco Modigliani and James Duesemberry.

While in these early articles he did not developed Lombardini's criticism of structural economic modeling, he came to express a growing skepticism of the ability of these models to capture economic reality. Beside the unrealistic assumption of linearity (especially when major changes occurred in some exogenous variables) and the problems involved in the inclusion of expectations and qualitative or institutional change, Pasinetti was particularly concerned with the instability (and unreliability) of aggregation:

> [le] variabili aggregate non possono tener conto delle variabili relative del gruppo che è stato aggregato. Inoltre quando si passa senza far distinzioni, come si usa frequentemente, da un'analisi del comportamento delle singole unità economiche al comportamento del loro insieme, si suppone implicitamente un'identità, che in realtà non è sempre perfetta, tra il comportamento dei singoli soggetti e quello della collettività. In particolare una siffatta identità non si verifica allorché le decisioni dei singoli soggetti economici non sono tra loro indipendenti (Pasinetti, 1956, p. 149).

Pasinetti's growing dissatisfaction with structural econometric models was of a deep theoretical nature. The aggregation of many different economic processes could

[4] On the development of econometrics in Italy and its impact on policy making see Rey (2004); Lavista (2010).

encroach the autonomy and reliability of the structural relations as emerging from empirical observation. A methodological refoundation was implicitly invoked by the young Italian economist:

> Ben altro è invece il significato delle relazioni basate su profonde elaborazioni teoriche, le quali, tendendo ad individuare le cause più remote che determinano i fenomeni considerati, si propongono di spiegare non solo i risultati praticamente realizzati, ma anche i possibili risultati che si sarebbero potuti verificare sotto diverse condizioni … E' in questa direzione infatti, cioè nella possibilità di nuove elaborazioni nel campo economico, che ci sembra possano scaturire i maggiori contributi alla costruzione e allo sviluppo dei modelli econometrici (Pasinetti, 1957a, p. 62).

It is to be noticed how at the time Pasinetti was falling, as a graduate student, under the powerful intellectual influence of the Cambridge (UK) school. In 1957 he was attending Kaldor's courses on growth and income distribution and reading Joan Robinson's *The Accumulation of Capital* (1956). A clear testimony of the rapid changes occurring in his way of reasoning is offered by a brief note, presented in a Conference organized by the CISL trade-union, in which Pasinetti, in a style very similar to Harrod's and Robinson's dynamics, developed a simple model of a dual economy with productivity differentials and different stages of economic developments, where a repression of wages in the core economy led to a relative stagnation of aggregate demand, inadequate innovation and lower capital accumulation with structural unemployment (Pasinetti, 1957b). In the following years, during his PhD training in Cambridge, Pasinetti completely abandoned his original and appreciated research efforts in econometric modeling and devoted himself to economic theory along the lines drawn by Kaldor, Robinson and Sraffa. As we shall see in the next sections his major works of the 1960s, dwelling on the relationships between growth, full employment and income distribution, were all grounded upon a strong notion of causality.

One of the first occasions in which Pasinetti had the opportunity to clarify his concept of causality was the inaugural lecture he gave in 1964 for the Course of econometrics at the Catholic University of Milan, that he devoted to "Causalità e interdipendenza nell'analisi econometrica e nella teoria economica" (Pasinetti, 1965). Pasinetti presented his notion of causality by making resort to two alternative logical structures representing the relations among economic variables. A first logical structure may be represented by a system of equations where, given a set of parameters taken as exogenous, all the endogenous variables can be determined starting from any of the equations of the system. This type of structure, perfectly simultaneous and symmetric, is named, according to Pasinetti (but following Simon), an "interdependent" system (1).

$$\begin{aligned}
&\alpha_{11}x_1 + \alpha_{12}x_2 + \alpha_{13}x_3 + \cdots + \alpha_{1n}x_n = \alpha_1 \\
&\alpha_{21}x_1 + \alpha_{22}x_2 + \alpha_{23}x_3 + \cdots + \alpha_{2n}x_n = \alpha_2 \\
&\alpha_{31}x_1 + \alpha_{32}x_2 + \alpha_{33}x_3 + \cdots + \alpha_{3n}x_n = \alpha_3 \\
&\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (1) \\
&\alpha_{n1}x_1 + \alpha_{n2}x_2 + \alpha_{n3}x_3 + \cdots + \alpha_{nn}x_n = \alpha_n
\end{aligned}$$

$$
\begin{aligned}
&\beta_{11}x_1 && = \beta_1 \\
&\beta_{21}x_1 + \beta_{22}x_2 && = \beta_2 \\
&\beta_{31}x_1 + \beta_{32}x_2 + \beta_{33}x_3 && = \beta_3 \\
& \\
&\beta_{n1}x_1 + \beta_{n2}x_2 + \beta_{n3}x_3 + \cdots + \beta_{nn}x_n && = \beta_n
\end{aligned} \tag{2}
$$

A second logical structure (2) is represented by an asymmetric system of equations in which some endogenous variables must be determined before and independently of the remaining variables, so that a logical order emerges in the solution of the system: while the first equation must be resolved first and independently from the others, the last equation can be solved only when all the previous equation have been solved:

> Qualsivoglia delle *n* equazioni prese in considerazione, si constaterà subito che quella equazione può essere risolta soltanto dopo che sono state risolte tutte le equazioni che la precedono, e nello stesso tempo ignorando tutte le equazioni che la seguono. Ciò significa che c'è tra le variabili o incognite del sistema, una relazione di carattere asimmetrico: una relazione che procede in una direzione sola, e non nella direzione opposta. Cosicché la y_n dipende dalla y_1, ma la y_1 non dipende dalla y_n. E' appunto questa relazione asimmetrica tra le variabili che viene chiamata "causalità". E la disposizione in cui le equazioni sono state poste – secondo la catena di dipendenza che le lega – si chiamerà "ordine causale" o "catena causale" (Pasinetti 1965, p. 237).

This second type of structure is labeled, following Simon, "causal order" and, following Wold, "causal chain"[5]. In supporting the case for the adoption of causal structure in economic modeling, Pasinetti makes clear that he does not want to deny the existence of relevant interdependent relations underpinning economic reality: rather causal or recursive system may be composed by sub-systems of interdependent equations linked together in a causal chain. Thus, in a system like III, two equations ordered in a causal way are followed by a sub-system of simultaneous equations, which, once resolved, determines on its turn a second block of simultaneous equations.

$$
\begin{aligned}
&\gamma_{11}z_1 &&&& = c_1 \\
&\gamma_{21}z_1 + \gamma_{22}z_2 &&&& = c_2 \\
&\gamma_{31}z_1 + \gamma_{32}z_2 + \gamma_{33}z_3 && + \gamma_{34}z_4 && & = c_3 \\
&\gamma_{41}z_1 + \gamma_{42}z_2 + \gamma_{43}z_3 && + \gamma_{44}z_4 && & = c_4 \\
& && + \gamma_{54}z_4 + \gamma_{55}z_5 && + \gamma_{56}z_6 & = c_5 \\
& && + \gamma_{64}z_4 + \gamma_{65}z_5 && + \gamma_{66}z_6 & = c_6 \\
&\ldots \\
&\gamma_{n1}z_1 + \gamma_{n2}z_2 + \gamma_{n3}z_3 && && + \gamma_{nn}z_n & = c_n
\end{aligned} \tag{3}
$$

[5] Actually Simon's "causal order" is a much broader and general concept, encompassing but not coinciding with that of "causal chain" or "recursive system" as formulated by the Swedish school. While the former is formulated in strictly logical terms and does not necessarily imply a time sequence between cause and effect, the latter is certainly more open to a deterministic interpretation and strictly time dependent (Strotz and Wold, 1960; Drakopoulos and Torrance, 1994, p. 185-187 for a discussion).

Mentioning the notorious criticisms to the concept of causality stemming from logical positivism, Pasinetti adopted the formal notion proposed by Simon (1953): causality is to be intended as an analytic characteristic of the relation among the variables within a system rather than a feature of economic reality:

> non è … un discorso di carattere ontologico, ma di carattere logico. I due sistemi, di equazioni interdipendenti e di equazioni causali, sono stati presentati come due schemi logici. E la definizione di catena causale che è stata data non contiene in se stessa alcuna affermazione circa la realtà empirica. Ha semplicemente il significato di una relazione asimmetrica tra le variabili di uno schema logico (Pasinetti, 1965, p. 239).

Moreover Pasinetti discussed the application of the different logical structures to econometrics, suggesting that recursive and causal models present remarkable features of simplicity and robustness[6], while interdependent models need more complex transformation and arbitrary assumptions in order to resolve the problems of identification and overcome the correlation of probabilities between variables and errors[7]. La forma ridotta dei sistemi interdipendenti, che è di tipo causale, permette di

> applicare metodi di stima meno laboriosi per poi ritrasformare i parametri della forma ridotta nei parametri – da cui derivano – nella forma originaria, cosiddetta "strutturale". E in ogni caso, questo procedimento richiede delle condizioni particolari – la cosiddetta identificazione dei modelli econometrici – che non corrispondono affatto alla generalità. Negli altri casi bisogna seguire il laborioso procedimento di effettuare le stime dei parametri direttamente sulla forma strutturale. … Resta il fatto che l'impiego dell'inferenza statistica con l'uso di relazioni di tipo interdipendente richiede, oltre che i calcolatori elettronici, una serie di assunzioni e ipotesi, e di prove di queste ipotesi, che non sarebbero necessarie nel caso di relazioni di tipo causale (Pasinetti, 1965, p. 241).

Pasinetti highlighted how econometric research, especially in the United States, devoted huge human, financial and technical resources, seeking to overcome the problems of structural econometric modeling, while the relatively simple techniques associated with process analysis were apparently cast away and dismissed as devoid of scientific dignity. The reason for this apparent paradox was to be looked in a strong theoretical commitment on the part of mainstream economics, to develop macroeconomic analysis along the lines of Walrasian general equilibrium model. In this

[6] The estimation of parameters' values is relatively simple in the case of recursive systems: "una equazione lineare in cui la variabile dipendente sia una funzione di variabili pre-determinate (vuoi perché esogene al modello considerate, vuoi perché endogene al modello, ma con ritardi temporali, vuoi perché semplicemente predeterminate da un'altra relazione) cioè il caso di una relazione causale … la distribuzione probabilistica delle variabili – pre-determinate su cui si effettua la regressione, risulta non correlata con la distribuzione probabilistica degli errori residuali. Si può dimostrare che, in tal caso, il momento di primo ordine dei residui intorno alla media è zero e che il momento di secondo ordine tende al corrispondente momento di primo ordine col crescere delle dimensioni del campione. L'applicazione del più semplice metodo di stima dei parametri che conosciamo, quello dei minimi quadrati, ci dà delle stime coerenti (cioè che tendono al valore teorico col crescere della dimensione del campione) e non distorte (cioè il cui valore atteso coincide col valore del parametro)" (Pasinetti, 1965, p. 240).

[7] In the case of interdependent relations: "la distribuzione probabilistica degli errori di ogni equazione si trova in questi casi ad essere correlata con la distribuzione probabilistica delle variabili non predeterminate. Per ottenere delle stime parametriche coerenti e non distorte …. occorre ricorrere a metodi molto più complessi, come per esempio quello della massima verosimiglianza, che comportamento dei computi laboriosi, lunghi e complicati" (Pasinetti, 1965, p. 241).

context Pasinetti recalled the efforts undertaken by the Swedish school guided by Wold to develop a causal and dynamic approach to econometrics that Siro Lombardini had long been supporting but most of econometricians had abandoned in search for interdependent structural models. The debate within econometrics brought to light the existence of two different way of looking to macroeconomics which was dividing the profession in two distinct and opposing fields:

> Le discussioni che si sono svolte tra econometristi appaiono, in questo quadro, come un aspetto particolare di tutta una controversia più vasta, che sta alla base di tutta la teoria economica. E' un episodio particolare, sì, e tuttavia interessante: per la prima volta questi due schemi logici emergono a contorni ben definiti per esigenze di ordine concreto: quelle di quantificazione, o stima, dei parametri delle relazioni economiche (Pasinetti, 1965, p. 246).

Walrasian general equilibrium model gave rise to structural economic models in which the relationship among the endogenous variables should be fully interdependent and perfectly symmetrical. Static comparative analysis should compare the reaction of the system to different external shocks, so that causality could run only from exogenous to endogenous variables. Any internal dynamic process was denied or dismissed as irrelevant: given the set of parameters the final equilibrium was uniquely determined by the new values of the exogenous variables. Equilibrium analysis did not need any inquiry on the process of disequilibrium (for a discussion see Vercelli, 1991, chapter 2). These features responded to a precise vision of the economic system in which social interaction in the market place occurred between myriads of individuals, each of them endowed with a different set of resources and preferences, but not qualitatively different from each other and, in any case, never able to exert any conscious and relevant power on the final outcome of the whole economic process.

In the following sections we will consider some among the major works by Luigi Pasinetti, where the specification of one or more relations in causal terms plays an essential role to convey an economic result that would emerge less clearly, or would not emerge at all if the same relations were represented in an interdependent way.

3. Causality in Ricardian analysis

Let us start from Pasinetti's approach to Ricardo. In the aforementioned inaugural lecture Pasinetti says:

> [c]onsider, for example, the Ricardian central theory — that of the distribution of global income among the various social groups participating the production process[8]. — the various categories of incomes are determined according to a clear sequence: wages first (on the basis of the physiological necessities of life), then rent (according to the varying fertility of the soil) and finally profits, as residual income (Pasinetti, 1965, p. 244, our translation).

This causal ordering emerges very clear from the one industry Ricardian model proposed by Pasinetti (1977, chapter 1, § 3.1) elaborated on the basis of Kaldor (1956, §

[8] D. Ricardo, *On the Principles of Political Economy and Taxation*, London, 1821.

I). Let $Q_c = f(N_c)$ be the corn produced as a function of the number, N_c, of workers employed in producing corn,

$$W = \bar{x}N_c \tag{4}$$

be total wages ($\bar{x}$ being the unit subsistence wage) and

$$R = f(N_c) - N_c f'(N_c) \tag{5}$$

be the rents determined according to the varying degree of fertility of the various pieces of land put into cultivation. Profits and the rate of profit are determined by

$$P = Q_c - W - R = N_c[f'(N_c) - \bar{x}\,] \tag{6}$$

and

$$r = \frac{f'(N_c) - \bar{x}}{\bar{x}}\,. \tag{7}$$

After deducing rents, profits are the surplus of corn over wages obtained on the marginal land. The residual character of profits reflects the primacy of capitalists in the production process. This view requires precise *causal* ordering: all magnitudes concurring to calculate profits, that is, output of corn, wages and rents are *priorly* known *before* profits are determined. It is easy to observe that these magnitudes depend all on N_c, which in the one industry model is entirely determined by the amount of capital available, $\bar{K}$, and by the subsistence wage rate:

$$N_c = \bar{K} / \bar{x}\,, \tag{8}$$

being capital constituted only by the anticipations of wages to workers at the beginning of the productive process.

It can been observed (see, for example, Costa, 1977, §1), that the clearness of these results is soon put at risk if the analysis is extended to a second industry, 'gold' in the Pasinetti formulation (see 1960 and 1977, chapter I, § 3.2-3.5), due to the fact that N_c requires a more complex determination. Still, capital is entirely constituted by the anticipation of wages but, in this case,

$$N_c + N_g = \bar{K} / \bar{x}\,, \tag{9}$$

where N_g are workers employed in the gold industry. Gold is produced under constant returns to scale, on the basis of the following production function

$$Q_g = \alpha N_g, \qquad \alpha > 0 \tag{10}$$

Total profits are given by

$$P = P_c + P_g = (p_c Q_c - p_c R - p_c \bar{x}\, N_c) + (p_g Q_g - p_c \bar{x}\, {}_c N_g) = N(1 - p_c \bar{x}\,) = \frac{\bar{K}}{\bar{x}}\left(1 - \frac{\bar{x}}{f'(N_c)}\right);$$

hence, the rate of profit,

$$r = \frac{P}{p_c \overline{K}} = \frac{f'(N_c) - \bar{x}}{\bar{x}},$$

has the same form found in the one-industry model (7), that is it is still determined by the surplus of corn obtained on the marginal land, due to the assumption of a single capital good. In order to split workers between the two sectors it is necessary to determine the composition of total expenditure. Pasinetti thus resorts to a theory of expenditure (1960, p. 84) or a theory of demand (1977, p. xxx). He supposes that workers and capitalists spend their incomes (wages plus profits) in corn (the formers as necessities, the latters for capital accumulation), while land-owners spend their rents entirely in gold. To this purpose it is sufficient to specify the expenditure land-owners:

$$p_g Q_g = p_c R. \tag{11}$$

But in this case the *causal* ordering characterizing the one industry case is immediately lost! The system of equations regulating income distribution (4), (5) and (6) are no longer closed by the knowledge of the amount of available capital which, by (8), determined the amount of corn produced. Income distribution now depends also on final demand and, finally, on prices. For example, it is sufficient to subvert the assumption that land-owner consume just gold to see the breakdown of the causal structure. Suppose that a fraction $(1 - \beta)$ of rents are spent on gold, while a fraction β are spent on corn, $0 \leq \beta \leq 1$. Equation (8) becomes[9]

$$p_g Q_g = (1 - \beta) p_c R. \tag{8′}$$

Substitute (10), (5) and (9) in equation (8′); re-arrange:

$$\frac{\overline{K}}{\bar{x}} = (1 - \beta) \frac{f(N_c)}{f'(N_c)} + \beta N_c. \tag{12}$$

If $\beta = 0$, that is, rents are entirely spent on gold, like in Pasinetti's case, equation (12) determines N_c:

$$\frac{\overline{K}}{\bar{x}} = \frac{f(N_c)}{f'(N_c)}. \tag{13′}$$

Let N_c^* be the solution of (14′), that is the number of workers employed in the industry of corn in the case that rents are entirely spent on gold. As we relax this extreme assumption, and we allow for a consumption of corn also by land-owners, β moves from zero to a positive value; accordingly, the solution for N_c, and thus all the fundamental variables of the system, that is, rents, profits, the rate of profit and the price of corn, will change with β, that is, with changes of final demand!

[9] As in the case considered by Pasinetti, this demand equation is sufficient to specify the demand of the corn, which now equals wages + profits + a fraction β of rents. In fact, by substituting (8′) into the expression of profits, $rp_cK = p_cQ_c + p_gQ_g - p_cR - wN$, we have $rp_cK = p_cQ_c + \beta p_cR - wN$, that is, $p_cQ_c = wN + rp_cK + \beta p_cR$, which is the relation required.

The dependence of profits on prices, which was accurately put out of the door by Pasinetti's assumption to that in the system there is only one capital good (which coincides with the device used by Ricardo in his early writings to consider 'corn' as that commodity having the property of being both the input and the output of its production) returns through the window by closing the system by a demand theory.

Which difference would have the present model from a general equilibrium system? Just a disequilibrium on the labour market, induced by the assumption of a given real wage rate (equal to the subsistence level), and the labour theory of value,

$$p_c = 1/f'(N_c) \quad \text{and} \quad p_g = 1/\alpha,$$

induced by the simplifying assumption of a single wage good. By the way, relative prices would come to depend on N_c, that is, on final demand, in contrast to the conclusion drawn by Pasinetti that "it appears that the value of commodities depends exclusively on technical factors (the quantity of labour required to produce them) and on nothing else" (Pasinetti, 1960, p. 85), as argued by Costa (1977, § 1). From the formal point of view this argument is correct: we are in a *simultaneous* equation system.

There is, however, a better light through which it can be looked at. As known, it is common in the Classical approach to distinguish between two levels of analysis: one, more fundamental, where the relations between the distributive variables and the normal prices of commodities are described, and a second level, where the 'institutional' aspects, in a broad sense, are taken into account.[10] The Ricardian system here outlined is a typical example where this distinction is relevant. Relation (11) is a relation which attains to an institutional aspect (or it is better studied 'outside of the core'). It describes the behaviour of land-owners in spending rents and, complementary, the behaviour of workers and capitalists in spending wages and profits, respectively. It may be contingent with the historical phase (like the assumption of a subsistence wage rate[11]). Hence, equation (11) is just *one* of the possible ways to close the Ricardian system, but other alternative solutions could be adopted to the purpose, but none of these solution has a priority over the others one. In other words, while the determination of wages exogenously to the core of the system, expressed by equation (4), the principle of differential rent, expressed by equation (5), and the determination of profits as a surplus

[10] Pasinetti distinguishes between a 'natural' and an 'institutional' level. Garegnani (1984), distinguishes between a 'core' of the system and the relations 'outside of the core'. These distinctions do not overlap, but share several common characteristics. An analysis and a comparison between these distinctions are object of a current research put forward by one of us.

[11] As outlined by Garegnani 'Thus, at a closer inspection, what all these authors had in common was not, as is often held, the idea of a wage determined by subsistence. It was the more general notion of a real wage governed by conditions (often of a conventional or institutional kind) that are *distinct* from those affecting the social product and the other shares in it, and are therefore best studied separately from them. This separation between the determination of the wage and that of the social product is evident when, as in Quesnay or Ricardo, the wage is explained in terms of a customary subsistence, but the same separation between the two problems emerges in Marx and Smith, who admitted a greater influence of current economic conditions on the real wage. It is this separate determination of the real wage that is expressed in its treatment as a magnitude which is known when the determination of the other shares of the product is approached" (Garegnani, 1984, pp. 295-6).

are *permanent* characteristics of the economy here described[12], the determination of the proportions between sectors reflects *transitory* elements, ultimately to be ascribed to habits, customs, historical circumstances, etc; in brief, institutional elements.

It is under this perspective that the choice made by Sraffa (1960, p. v) to *not* consider changes in output can be appreciated: any endogenous determination of output re-introduces all that series of interdependencies that it is better to neglect at this fundamental stage of analysis, being this determination subject to various, transitory and often not univocal forces (for a detailed analysis of this supposition, as a peculiar feature of the method of Classical economists, see Garegnani, 1984, Section II; see, also, 2007). By following this suggestion, the Ricardian model proposed by Pasinetti, recovers immediately the causal structure necessary to ground an explanation of profits based on the notion of surplus. Let $\overline{Q}_c$ and $\overline{Q}_g$ be the given quantities of corn and gold produced. Through the respective production function we obtain immediately the total labour requirements to produce those quantities: $N_c^* = f^{-1}(\overline{Q}_c)$ and $N_g^* = \overline{Q}_g / \alpha$.[13] Prices, wages, rents, profits and the rate of profit are thus univocally determined:

$$p_c = 1/f'(N_c^*) \quad \text{and} \quad p_g = 1/\alpha,$$

$$W = \bar{x}(N_c^* + N_g^*),$$

$$R = f(N_c^*) + N_c^* f'(N_c^*)$$

$$P = (N_c^* + N_g^*)\left(1 - \frac{\bar{x}}{f'(N_c^*)}\right) \quad \text{and} \quad r = \frac{f'(N_c^*) - \bar{x}}{\bar{x}}.$$

All crucial characteristics of the Ricardian theory of value and distribution claimed by Pasinetti return to be true: i) the sequential determination of distributive variables and, in particular, the residual character of profits, as emphasized in the quotation by Pasinetti (1965) reported here at page XXX; ii) "a theory of value which is completely and (owing to our explicit assumptions) rigorously independent of distribution" (Pasinetti, 1960, pp. 84-5) and iii) "a theory of income distribution which is independent of the theory of value" (Pasinetti, 1977, p. 15).

[12] As regards the wage equation (4) the 'permanent' aspect lies in the fact that $\bar{x}$ is taken exogenously; the principle that determines this exogenous level of $\bar{x}$ may be different from time to time and from society to society; for this reason it is 'transitory'.

[13] In this case it is no longer true that $\bar{x}(N_c^* + N_g^*) = \overline{K}$; we must introduce the supposition that that $\bar{x}(N_c^* + N_g^*) \leq \overline{K}$. Alternatively, we may drop the supposition that the stock of capital is given; the amount of capital necessary to produces the given quantities $\overline{Q}_c$ and $\overline{Q}_g$ would thus come to be determined endogenously by the model.

4. Causality in Keynesian analysis

Pasinetti highlights how the main pillar of Keynes' *General Theory* is the *principle of effective demand*, according to which, below full employment, the level of aggregate output Y of an industrial economy, is *determined* by the level of aggregate effective demand D, constituted by consumption, C, investments, I, and public expenditure, G (for simplicity, we abstract from imports and exports). This principle represented a break with the tradition that held aggregate output be co-determined by the interaction of supply and demand forces and full employment be attained by means of price and wage adjustments. Evidently this principle should be represented by a *causal* equation, in the sense that $D \rightarrow Y$ (Pasinetti, 1974, pp. 46-48). A second element of Keynes' theory was an explanation of the rate of interest, r, essentially *as a purely monetary phenomenon*. This represented a break with the tradition that saw the rate of interest as the price of capital, determined by the interaction between the demand of investment and the supply of savings. To this purpose, Keynes was careful to link aggregate consumption, C, just to national income, Y (and not to r): $C = A + cY$, where A is the autonomous consumption and $c \in (0,1)$ is the marginal propensity to consume. In this way, aggregate savings turn out to be released by r and are given by $S \equiv Y - C - G = -A - G + (1 - c)Y$. On the contrary, investments are not put in relation with national income; they depend positively on their expected profitability, E, and negatively on the rate of interest, $I = I(E, r)$.[14] According to Pasinetti (1974, p. 37) entrepreneurs rank investment projects according to their decreasing expected profitability and carry out investments up to the point at which the expected rate of profit of last project (the 'marginal efficiency of capital') is higher than or equal to the rate of interest. Hence, a decrease of the rate of interest enlarges the number of project carried out. It is thus necessary to explain what determines the rate of interest. This is the third original contribution given by Keynes: the *liquidity preference* function. Individuals prefer to keep their wealth in a liquid form (for transactions, precautionary and speculative reasons), unless a positive interest rate is paid if the same amount of wealth is kept in less liquid financial activities; hence the demand for money is inversely related to the rate of interest: $L(r)$. The Central Bank fixes the amount of money supplied, $\overline{M}$; the rate of interest is thus given by the solution of

$$L(r) = \overline{M}, \quad \text{that is,} \quad r = r^*. \tag{15}$$

Hence, given the state of business expectations regarding the future return on new investments (here summarized by symbol E) the level of investments is given by[15]

[14] This Ricardian interpretation of the notion of the 'marginal efficiency of capital'—which looks like to a sort of possible re-interpretation of Keynes investment theory rather than an attempt to interpret what Keynes actually thought—is not shared by other authors; Garegnani for example considers the 'marginal efficiency of capital' "the price which Keynes has to pay for the traditional strand in his thought" (1979, p. 78): the traditional principle of substitution between capital and labour should be thus at the root of the inverse relation between I and r. On this point see also Tonveronachi 1983, p. 169.

[15] As the expected profitability of investments (denoted by symbol E) is to be considered as independent of the other endogenous variables of the system, we will omit to indicate explicitly it in the rest of the paper, and we will write $I = I(r)$. A criticism is raised on this point by Garegnani (1979, p. 78fn), who

$$I^* = I(r^*). \tag{16}$$

Effective demand, $D = A + cY + G + I(r)$, depends thus on national income only; by the principle of effective demand, $Y = D$, we are thus able to determine the equilibrium levels of national income and of consumption:

$$Y^* = \frac{1}{1-c}[A + I(r^*) + G] \quad \text{and} \quad C^* = A + cY^*. \tag{17}$$

Pasinetti highlights that an evident *causal* ordering regulates the relationship between the rate of interest—which is determined by the equilibrium on the money market—and investments—which are determined by the marginal efficiency of capital and the rate of interest—. An *interdependent* sub-system determines the remaining variables, national income, (savings) and consumption.

In Pasinetti's view such a hierarchical determination of the endogenous variables does not reflect just a formal property. It is fundamental in conveying substantial results of Keynes' system.

K1) A first result is the process of generation of national income: it is ultimately determined by expenditure decisions: A, $I(r^*)$ and G.

K2) A second relevant result is the relation between investments and savings: investments are an exogenous variable with respect to the sub-system which determines national income. Savings adjust themselves passively to the investments level: $S = Y - C - G = (C + I + G) - C - G = I$. Given *any* level of I, as determined by equation (16), the principle of effective demand will give rise exactly to that level of national income which will ensure the amount of savings necessary to finance that level of investment.

After reflection, it can be seen that this *causal relation* between I to S (i.e., $I \rightarrow S$) rests on the possibility to consider investments as given with respect to the process which generates national income and savings. Not surprisingly the unhinging of this property was the starting point of the Neoclassical synthesis. Paradoxically, the evidence for this 'generalization' is provided in the 15th chapter of the *General Theory* by Keynes himself, who acknowledges that the demand for liquidity for transaction- and precautionary-motives depends on the level of national income. The functional form of the liquidity preference function would become thus $L_1(Y) + L_2(r)$, where $L_1(Y)$ is the liquidity demanded for transaction- and precautionary-motive and $L_2(r)$ is the liquidity demanded for speculative-motive. The equilibrium of the money market is thus represented by the condition

$$L_1(Y) + L_2(r) = \overline{M}\,, \tag{15′}$$

where $\overline{M}$ is the stock of money provided by the banking system. System (15′), (16) and (17) is now a fully *interdependent* system. The causal determination of endogenous

says: "there are some arguments for which the assumption of prospective yields and prices independent by the ruling interest rate does not seem acceptable".

variables contained in equations (15), (16) and (17) and, consequently, the properties K1) and K2) above are thus immediately lost!

> In this way, consumption (but he says savings) is made to depend not only on income but also on the rate of interest, and demand for money is made to depend not only on the rate of interest but also on income. At the end of this, apparently innocuous, manipulation, Hicks has in fact broken up Keynes' basic chain of arguments. The relations have been turned into a system of simultaneous equations, i.e. precisely into what Keynes did *not* want them to be (Pasinetti, 1974, p. 46).

In his 1974 essay Pasinetti does not make clear the arguments that Keynes offered to deny the alleged influence of income on the demand for money and thus on the rate of interest. He mentions the quarrel on the *finance motive* which developed immediately after the publication of the *General Theory* with Dennis Robertson, before presenting an interesting model of how the multiplier process shall lead to equate total savings to the realized investments only after its completion.

The finance motive quarrel shows how stubbornly, though not without falling in some inconsistency and indecision, Keynes strove to maintain that savings and investments do not exert any influence on the rate of interest and thus preserve its purely monetary nature[16]. Yet Keynes did not pay much attention to the IS-LM model (which he declared, in a letter to Hicks, to have "found it very interesting and really have next to nothing to say by way of criticism") and tended to assimilate Hicks' interpretation of the rate of interest to that presented by Ohlin and Robertson.[17]

Anyway, Pasinetti has had his own reasons for thinking that the economic system outlined in the *General Theory* is better represented by the *causal* system (15), (16) and (17) instead of the interdependent system (15′), (16) and (17). In actual economic system it is reasonable to assume that the banking system and the central bank tries to satisfy in each period the fluctuation of the money demand for transactions- and for precautionary-motives with suitable changes in the stock of money supplied, so that the term $\overline{M} - L_1(Y)$ can reasonably be considered as a constant, and (15′) returns to be an equation in the single unknown r:

$$L_2(r) = \underbrace{[\overline{M} - L_1(Y)]}_{\text{consant}}, \qquad (15'')$$

and a *causal* ordering is thus re-established in system (15″), (16) and (17).

Pasinetti's view may be in line with more recent interpretations of Keynes' monetary theory offered by other streams of Post-Keynesian literature. For example,

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[16] On this point see Trevithick (1994, 84-85) and Cesaroni (2001, pp. 62-63). The debate on the finance motive revived in the 1980s between monetarist and post-keynesian interpreters of Keynes's monetary thought. While Asimakopulus (1983) highlights a disequilibrium between saving and investments before the end of the multiplier process, Graziani (1984, 1986), Terzi (1986, 1987), Kregel (1986) and Davidson (1986) presented the view that "irrespective of the saving decisions being taken on the income that derives from the expenditures of fixed capital finance, at the end of the circulation period an adequate quantity of long term finance will be available to restore the initial liquidity position of the banks", Cesaroni 2001, p. 63.

[17] CWJMK, XIV, pp. 202-205.

Wray (1992) reconciles Keynes theory of liquidity preference as presented in the *General Theory* with the endogenous money supply typical of the *Treatise on Money*. A growth of national income due to additional governments expenditures will be associated with an increased demand for money for transaction and precautionary-motives.[18] Yet the additional demand deriving from the above mentioned motives can be smoothly satisfied by the banking system, which will be willing to expand its credit facilities at the current rate of interest. While money supply shall spontaneously accommodate income growth, the rate of interest will not be affected. On the contrary an increase in liquidity preference affects directly the rate of interest (and the price of other assets) and shall not be met by the banking system with an increase in the money supply: banks themselves will exert demand for new liquidity, will retain the liquidity they own and lower their asset/reserve ratio.[19]

5. Causality in structural change analysis

The interactions between causal and interdependent relations plays a fundamental role also in the most accomplished work presented by Pasinetti, i.e. the framework to analyse the structural change of a growing economy. There are at least two levels where this distinction is crucial: the choice to represent the production processes in vertically integrated terms and in the way in which the dynamics of output is studied without compromising the logical structure of the surplus approach.

5.1. Vertically integrated representation of production processes

Consider a system where C final commodities are produced by employing capital goods and labour. Let $c = 1, ..., C$ be the index corresponding to each commodity. For simplicity, we will consider the case where capital goods are produced just by labour.[20] We represent this economy by means of a closed Leontief system, i.e. a model which is typically employed to represent inter-industrial *interdependences*. But the aim of the analysis is that of investigating how the *dimension* and the *structure* of an industrial economic system evolve as a result of the joint pressure of: i) population change, ii) technical change and iii) the change of final demand composition. Element i) operates substantially on the scale of the system, but elements ii) and iii) operate also on the *composition* of intersectoral relations. In analytical terms, let

[18] The finance motive stemming from the disequilibrium between saving and investment during the multiplier process could be added as a third factor.

[19] The central bank shall be called to expand its own supply of liquidity to the banking system and engage in open market purchases in order to drive asset prices up and interest rates down: in this case money supply apparently ceases to be endogenous, a point which Wray fails to notice (Wray 1992: 86-87). Anyway, while the central bank may be able to counteract the upward pressure of liquidity preference on interest rates and asset prices, it may fail to make commercial banks willing to purchase assets and expand their credit facilities. Uncertainty and liquidity preference shall still prevent a secondary expansion in the money supply to occur.

[20] The general case, with capital goods produced by capital goods and labour, is considered in Pasinetti (1981, chapter II, §7).

$$\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1C} & c_1 \\ a_{21} & a_{22} & \cdots & a_{2C} & c_2 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ a_{C1} & a_{C2} & \cdots & a_{CC} & c_C \\ \ell_1 & \ell_2 & \cdots & \ell_C & 0 \end{bmatrix},$$

be the matrix of input output coefficients, where the generic a_{ci} coefficient is the quantity of commodity c used to produce 1 unit of commodity i, ℓ_c is the quantity of labour necessary to produce 1 unit of commodity c and c_c is the per-capita consumption of commodity c. Element ii) above affects coefficients a_{ci} and ℓ_c while element iii) affects coefficients c_c; in addition, both ii) and iii) affect the number C of commodities used as final goods as well as as capital goods,

To set up a model where all these magnitudes change is quite a difficult task. The device adopted by Pasinetti has been that of measuring capital goods in terms of units of 'vertically integrated productive capacity' (see Pasinetti, 1981, chapter II, § 4). One unit of vertically integrated productive capacity of commodity c is the set of "heterogeneous physical quantities of the various commodities 1, 2, ..., C, which are directly and indirectly required as stocks, in the whole economic system, in order to obtain one physical unit of commodity c as a final good" (Pasinetti, 1973, § 4, notation adapted). Thank to this device the input of capital goods is represented by a single entry: $\delta_c = 1/T_c$, where T_c is the average life-time of the physical capital employed in the vertically integrated sector of commodity c;[21] by simplicity, we assume that this fraction is constant in each period of time. Moreover, let λ_c be the quantity of labour required to produce one unit of productive capacity of final commodity c; let j_c be the coefficient of individual demand of capital good c by the final sector (net investment); let N denote the population size. Let x_c and k_c be the quantities produced of final good c and of its productive capacity respectively, and let p_c and q_c be corresponding prices. Finally, let w be the wage rate and π_c the corresponding rates of profits (that for the moment are not assumed to be uniform among sectors). δ_c, T_c, l_c, λ_c, j_c, and N are the *data* of the model; x_c, k_c, p_c, q_c, w and the π_cs are the *unknowns* of the model. The quantity system is

$$\begin{bmatrix} 0 & \cdots & 0 & 0 & \cdots & 0 & c_1 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & \cdots & 0 & 0 & \cdots & 0 & c_C \\ \delta_1 & \cdots & 0 & 0 & \cdots & 0 & j_1 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & \cdots & \delta_C & 0 & \cdots & 0 & j_C \\ l_1 & \cdots & l_C & \lambda_1 & \cdots & \lambda_C & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ \vdots \\ x_c \\ k_1 \\ \vdots \\ k_C \\ N \end{bmatrix} = \begin{bmatrix} x_1 \\ \vdots \\ x_c \\ k_1 \\ \vdots \\ k_C \\ N \end{bmatrix}. \qquad (18)$$

[21] The case considered here is that capital goods last for more than one period (i.e., fixed capital); the case of circulating capital can be obtained as a particular case if $T_c = 1$ and, consequently, $\delta_c = 1$.

The first 2C equations of system (18) determine the quantities produced of each good according to its effective demand: the first C equations concern final goods; the second C equations concern the productive capacity of final goods, and show the two components of demand for productive capacity: replacement (δ_c) and net investments (j_cN). The last equation of system (18) establishes that in equilibrium, labour requirements (in producing final goods and their productive capacities) must equal the existing labour force.

The price system is:

$$\begin{bmatrix} 0 & \cdots & 0 & \pi_1+\delta_1 & \cdots & 0 & l_1 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & \cdots & 0 & 0 & \cdots & \pi_C+\delta_C & l_C \\ 0 & \cdots & 0 & 0 & \cdots & 0 & \lambda_1 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & \cdots & 0 & 0 & \vdots & 0 & \lambda_C \\ c_1 & \cdots & c_C & j_1 & \cdots & j_C & 0 \end{bmatrix} \begin{bmatrix} p_1 \\ \vdots \\ p_C \\ q_1 \\ \vdots \\ q_C \\ w \end{bmatrix} = \begin{bmatrix} p_1 \\ \vdots \\ p_C \\ q_1 \\ \vdots \\ q_C \\ w+\sum_{c=1}^{C}\pi_c q_c c_c \end{bmatrix} \qquad (19)$$

The first 2C equations of system (19) determine prices of final goods and of their productive capacities. The last equation of this system refers to *net* national income and states that in equilibrium wages plus profits must equal the expenditure for final and investment goods.[22]

The vertically integrated representation here adopted has hidden at once all inter-industrial interdependences, as a simple inspection of the matrices involved in systems (18) and (19) confirms: the sub-systems represented by the first 2C equations of both the quantity- and the price-system are formally *decomposable*; their solutions are, respectively,

$$x_c = c_c N, \qquad c = 1, ..., C, \qquad (18x)$$

$$k_c = \delta_c x_c + j_c N, \qquad c = 1, ..., C, \qquad (18k)$$

and

$$p_c = (\pi_c + \delta_c)q_c + wl_c, \qquad c = 1, ..., C, \qquad (19p)$$

$$q_c = w\lambda_c, \qquad c = 1, ..., C. \qquad (19q)$$

[22] Profits are calculated by applying the sectoral rate of profit to the value of the capital goods stock existing in the respective vertically integrated sector of final commodity c; the device to measure capital goods in terms of the unit of vertically integrated productive capacity entails that the number of units of vertically integrated productive employed in sector c coincides with the number final units of commodity c actually produced, i.e., x_c. Hence, total profits of the system are expressed by the sum $\Sigma_{c=1}^{C}\pi_c q_c x_c$. By solving the first C equations of the quantity system, one yields $x_c = c_c N$, $c = 1, ..., C$. Hence total profits can be re-expressed as $\Sigma_{c=1}^{C}\pi_c q_c c_c N$. The original formulation of the last equation of the price system is thus $\Sigma_{c=1}^{C}p_c c_c N + \Sigma_{c=1}^{C}p_c j_c N = wN + \Sigma_{c=1}^{C}\pi_c q_c c_c N$; after dividing by N we obtain the last equation of the price system as expressed in (19).

As regards the quantities, given N, (18x) determine, *immediately*, the output of final commodity: $x_c^* = c_c N$; *after substitution*, (18k) determine the output of new units of vertically integrated productive capacity, $k_c^* = \delta_c x_c^* + j_c N$. As regards prices, we *first* calculate the price of the capital good (i.e. productive capacity necessary to produce one unit) of final commodity c: $q_c^* = w\lambda_c$; *then* we can calculate the price of each final good, $p_c = (\pi_c + \delta_c)q_c^* + wl_c$.[23]

Hence, the technical interdependences among sectors are totally *disappeared*. Each vertically integrated sector remains defined by a couple of equations on the quantity side (one for the output of the final commodity and one for the output of the productive capacity) and a couple of equations for the price side (one for the price of the final commodity and one for the price of its productive capacity). Within each vertically integrated sector there is a hierarchy between each of the couple of equations, as described above. Finally, each vertically integrated sector is independent of the others, both on the quantity and on the price side.

However, interdependence reappears if we look at the system in its entirety, that is, if we impose the contemporaneous fulfillment of the 'macro-economic condition':

$$\sum_{c=1}^{C} l_c c_c + \sum_{c=1}^{C} \lambda_c j_c + \sum_{c=1}^{C} \delta_c \lambda_c c_c = 1. \qquad (20)$$

It is quite easy to verify that condition (20)—which is the necessary and sufficient condition to exclude trivial solutions to systems (18) and (19)—ensures at the same time: i) that the solutions of the quantity system satisfy also the last equation of system (18), that is, the full-employment condition and ii) that the solutions of the price system satisfy also the last equation of system (19), that is, the condition of complete expenditure of wages plus profits. The decomposability of systems (18) and (19) entails that it is possible to conceive situations where just the first $2C$ equations of the quantity system and/or the $2C$ first equations of the price system are satisfied, while the last equation of both system is not: we would have thus a sectoral equilibrium (as regards output and/or prices) and a macro-economic disequilibrium (on this, see Pasinetti. 1993, p. 23).

Thanks to the enormous simplifications made possible by the vertical integration, Pasinetti is now in the condition to introduce the dynamics of population, technical progress and the change in the tastes of consumers by assuming that

$$N(t) = N(0)\,e^{gt}, \quad l_c(t) = l_c(0)\,e^{-\rho_c t}, \quad \lambda_c(t) = \lambda_c(0)\,e^{-\rho'_c t} \quad \text{and} \quad c_c(t) = c_c(0)\,e^{r_c t}:$$

g is the growth rate of population, ρ_c and ρ'_c are the rate of decrease of labour coefficient in the final commodity vertically integrated sector and in the vertically

[23] As known, the price equations do not entail a unique configuration for income distribution. In the case of a uniform rate of profit and a uniform wage rate, we must fix outside the price equations or w or π. In the present case, with C rates of profits and a uniform wage rate, we must fix outside the price equations up to C among the variables π_1, ..., π_C and w. Obviously, a constraint must be imagined to hold, in order to avoid that some of these variables become negative.

integrated sector of its productive capacity (specularly, ρ_c and ρ'_c are the rates of increase of productivity of labour in the respective vertically integrated sector), and the r_cs are the rates of change of final demand of commodity c. In principle, $\rho_c \neq \rho_h$, $\rho'_c \neq \rho'_h$ and $r_c \neq r_h$ (by simplicity, N, l_c, λ_c and r_c are supposed to vary with *constant* rates of change; Pasinetti, 1981, pp. 82-3, suggests how this simplification can be removed).

The dynamics of all the parameters of systems (18) and (19) is thus specified but the dynamics of the per-capita investment coefficients, j_c. In order to set up a productive capacity for each final commodity c in line with the dynamics of its demand in each period, it is necessary that coefficients j_c evolve according to the following dynamic equilibrium condition:[24]

$$j_c(t) = (r_c + g)c_c(0)\,\mathrm{e}^{r_c t}\,.$$

It is remarkable how the operation of vertical integration makes it easy to describe the effects of technical progress in our system: a simple reduction of just *two* coefficients for each vertically integrated sector, l_c and λ_c; at the same time we may easily take into account the effects of a technical progress which operates *differently* in each sector. The same can be said for final demand.

5.2. Changing quantities and 'given quantities'.

Now we are able to consider a second sphere where the choice to avoid interdependencies reflects a well defined theoretical requirement. The framework of structural dynamics is considered by Pasinetti (2007, Book Three, and 2012) the main direction along which to develop the Sraffa's framework. As recalled at the end of Section 3, the assumption of given quantities, commonly adopted by old and modern classical economists in analysing the determination of profits and prices, is crucial in the surplus approach to avoid any co-determination between quantities and prices that could reintroduce a deterministic explanation of income distribution on the basis of demand curves of final goods and supply curves of productive factors (a detailed analysis of this point has been developed by Garegnani, 1983 and 2007). But in the structural change model, the quantities produced of the various commodities, as well as the quantities of commodities which are employed as means of production, *must* change in a framework which aims to describe the dynamics of the structure of an economic system. In other terms, on the one hand the dimension and the composition of the economic system must be considered as given when determining the rate of profit, the wage rate and relative prices; on the other hand both the dimension and the composition of the system must necessarily change if the system undergoes a process of structural change.

Now, it is easy to verify that the way followed by Pasinetti to introduce the dynamic in the model is fully compatible with the methodology of the surplus approach. In fact, the dynamics supposed for the parameters of the model (population, technical

[24] For details, see Pasinetti (1981, Chapter V, Section 4).

coefficients and final demand), which induce a structural dynamics on the endogenous variables of the model (quantities produced and prices),[25] is completely *independent* of these variables. This device prevents any possible double closure of the circuit (prices depending on quantities and quantities depending on prices) and keeps the structural change model fully compatible with the logical structure of classical theories. Any attempt to 'endogenize' the changes—sometimes invoked as a useful 'generalization' of the model—would be probably incompatible with the logic of the modern classical approach.

6. Final remarks

The reading of Pasinetti's 1966 essay *Causalità e interdipendenza nella teoria economica e nell'analisi econometrica* has allowed us to highlight the existence of a wide-ranging research program in Pasinetti works; since his early writings fundamental methodological issues were grounding an overall rethinking of modern economics along the lines of the classical-Keynesian approach. The complex relation between causality and interdependence was sorted by Pasinetti as an analytical device to characterize the nature of the classical-Keynesian approach and to emphasize its profound divergences with the marginalist and neoclassical paradigm.

The aim of this paper is to offer a first tentative inquiry into 1) how this research program was routed in Pasinetti's training as an economist and econometrician and 2) how the relationship between causality and interdependence was developed in Pasinetti's main theoretical contributions. In the first section of this paper we basically tackled the first issue, while each of following sections was devoted to the second one.

Is quite notorious how Pasinetti's research program was the outgrowth of his exposure to the Cambridge (UK) environment of the 1950s and 1960s. Yet, looking at Pasinetti's training during his graduation studies under Siro Lombardini's tutorship at the Catholic University of Milan, we are able to retrace quite a deep connection between the debates over econometrics in the 1950s and his later reflections on the nature of the conflict opposing modern Walrasian economics and the Classical-Keynesian approach.

This conflict, as Pasinetti presented since his 1966 essay, can be read in the light of the relationship between causality and interdependence in economic theory. Three main points emerged in this concern. 1. Causality had to be understood in the line of Herbert Simon's methodological proposals, not as a deterministic description of how reality actually is, but as a formal property of the model used to understand it; specifically a causal order emerges when a system of equations is asymmetric in nature, since it contains some equations that can be solved first and independently from the others, while the latter can be solved only when all the former equations have been solved. 2. Discovering and exploring the fundamental causal chains beneath the surface of economic phenomena was a commitment which posed a bridge between classical economic thought and the Keynesian one and which distinguishes it from the

[25] For a detailed description see Pasinetti (1981, Chapter V, Sections 9-12).

neoclassical approach. 3. In 1966 the difference between causality and interdependence parallels with the distinction between two level of analysis that will become the object of Pasinetti's 'separation theorem (separation between a purely economical-technical sphere and the institutional sphere). Pasinetti clearly pointed out that, while causality and interdependence could be helpful in understanding single economic contexts and phenomena, the "normative" or "potential" level of analysis (which he was later to label the "natural system") was the domain of causal relations only. The parallel between these classifications is not fully convincing (not all relations in the natural system are of the causal type, not all relations in the institutional system are of the interdependent type); and in subsequent writings Pasinetti does not underline any more the connection between these two methodological perspectives. Anyway, it is our opinion that in his later theoretical contribution, Pasinetti consistently pursued the discovery of Simons-causal type of relations, which he sorted as a primary target of his efforts as an economist (and, incidentally, it is probably one of the reasons why he never developed his initial econometric background). Hence, we have tried to follow him in his longstanding intellectual journey and to verify how the notion of Simon-causality entered in the main building blocks of his theory.

This interpretative effort has allowed us to clarify, at some critical points, how Pasinetti's thought took shape and to suggest some interpretation of why it did so. As a first step, reviewing the debate over Pasinetti's 1959 formulation of the Ricardian system, we realized how his reading was not immune from criticism. Pasinetti's early claims of a strictly causal chain in Ricardo's theory of income distribution were questionable as far as he determines the final demand choices simultaneously with the distributive variables of the model. Costa showed how the Ricardian system proposed by Pasinetti turned out to be fully interdependent. We have proposed one way to overcome Costa's argument by assuming given quantities of the final demand, in line with the methodology followed in the 'surplus approach'.

Another point of discussion rises with Pasinetti's presentation of Keynes' Principle of effective demand: effective demand represented, in his view, another fundamental causal chain running from the rate of interest to income, via investment decisions and the multiplier. Keynes' specification of his liquidity preference curve was called into the picture by Costa, in contending how the rate of interest itself is determined by the level of income, thus restating a full interdependence between consumption and saving decisions and the rate of interest. In this concern we tried to argue how Pasinetti's thought on this point closely followed Keynes' own insistence, in his post-*General Theory* discussions with Robertson and Ohlin, on the purely monetary nature of the rate of interest, whose level could not be affected neither by consumption and saving decisions nor by the level of income. We have provided an analytical support to this.

Our next step was to examine how causality and interdependence entered the Pasinetti framework of structural change. A first focal point is Pasinetti's attempt to overcome the straitjacket of structural interdependencies *à la* Leontief, from which he

patently drew inspiration but in which only a uniform growth of the system could occur. The analysis of structural change (i.e. a non-proportional growth of the various sectors of the economy) requires, instead, the interdependence between sectors to be broke up in favour of a causal chain running along intra-sectorial changes. The entire system appears as subdivided in sectors (one for each final commodity) operating in parallel one another: *technical* interdependences appear thus hidden by the device to represent the productive processes in vertically integrated terms. The Keynesian root of this framework establishes a Simon-causal relationship between final demand and the outputs of the various commodities; in the same way, the Classical root establishes a Simon-causal relationship between the labour content of commodities and their prices.

Pasinetti's choice to let the expansion of any sector be driven by an *exogenous* rate of growth in the final demand and an *exogenous* rate of change of technical coefficients avoids any sort of co-determination between prices and quantities which is at the basis of the theory of prices and of income distribution based on supply and demand curves. While the prices of commodities are determined by their expenses of production, the reward of the factors of production remains under the domain of the institutional setting of a society. It is true that an overall interdependence among all sectors reappears with the 'macro-economic condition', which relates the aggregate employment level to the level of expenditure of individual incomes (wages plus profits). Yet, this kind of interdependence is of a completely different nature from the one implied by Walrasian general equilibrium theory. No automatic mechanism takes care of the fulfillment of the above condition: the interaction of (private and public) institutions will determine the final outcome in terms of income distribution, level of economic activity, and employment.

As far as Pasinetti's notion of causality can be defined as a procedure by which complex economic processes may be decomposed and examined in a logical order, the aim of Pasinetti's investigation is to give priority to the human content of all economic processes and highlight the wide space of freedom (and common responsibility) that human societies have in determining their final outcomes.

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