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A dynamic linear economy with characteristic-based endogenous technical coefficients☆

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ABSTRACT

We develop a characteristic-based model for the endogenous determination of technical coefficients in a linear economy and use it to describe the dynamics of the economy as driven by changes in knowledge. The use of the characteristic approach to determine technical coefficients makes our model suitable to be interpreted as a first attempt towards the formulation of a formal knowledge-based model of technology.

1. Introduction

It is widely recognized that there is a close relationship between knowledge and technology: on the one hand, models of structural change (see, e.g., Pasinetti, 1981, 1993) and of endogenous growth (see, e.g. Romer, 1986) emphasize the role of knowledge in dealing with macroeconomic issues like sustained growth and employment; on the other, evolutionary theory (see, e.g. Winter, 1968; Nelson and Winter, 1977) considers knowledge an essential ingredient in explaining empirical facts like localized technical change, heterogeneity of firms' technologies and their dynamics. Since the localized nature of technical change makes the evolution of technology strictly intertwined with prices (see, e.g. Nelson and Winter, 1982), any complete analysis of localized technical change has to be carried out within a "general equilibrium" framework. Within this context, the evolutionary theory has repeatedly emphasized that the appropriate analytical framework to use is the multisectoral approach *à la* von Neumann–Leontief–Sraffa (see, e.g. Dosi and Grazzi, 2006, p. 296; von Tunzelmann and Wang, 2007, p. 208).[1]

Notwithstanding this state of affairs, no attempt has been provided so far even to construct a rigorous knowledge-based theory of production. Therefore, at the moment there is no theoretical foundation to the

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[1] David (1975) has actually shown that localized technical change yields production functions with fixed coefficients.

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knowledge-driven dynamics of technology, techniques and prices as considered by macroeconomic and multisectoral linear models and to phenomena like localized technical change, heterogeneity and dynamics of firms' technology as considered by the evolutionary theory.[2] Recent works by von Tunzelmann (2003) and Dosi and Grazzi (2006) provide interesting informal suggestions as well as conceptual contributions to this issue: von Tunzelmann (2003)[3] claims that Sen's capability approach (see Sen, 1985) is a promising framework to extend dynamic capability theory (see, e.g. Teece et al., 1997) to production theory. Since the capability approach is a characteristic-based approach (Lancaster, 1966a)[4] with a strong emphasis on the role of knowledge and skills in extracting characteristics, von Tunzelmann's claim represents a promising viewpoint for modeling the dynamics of an economy originated by the growth of knowledge. [5,6] Dosi and Grazzi (2006) point out the existence of a theoretical gap between the evolutionary procedure-centered representation of technology and the input/output-centered representation of technology, and they use the former approach to justify, within a Sraffa–Leontief approach, the "stylized facts" of asymmetries in productivities across and within firms, and heterogeneity of relative input intensities and their persistence over time (Dosi and Grazzi, 2006, p. 180). As already said, von Tunzelmann and Dosi and Grazzi explicitly refer to the "classical" linear production model *à la* von Neumann–Leontief–Sraffa as the most appropriate analytical framework within which to develop a model of an economy with a microfounded analysis of production along the proposed view, however, they do not provide any formal analysis of endogenous determination of technical coefficients and their dynamics.

In this paper we develop a characteristic-based model which allows the endogenous determination of the technical coefficients in a linear production model *à la* von Neumann–Leontief–Sraffa and apply this model to describe the evolution of the economy, in terms of technology, techniques, prices and distribution, as driven by changes in knowledge. Since we follow Sen's approach in interpreting the activity of characteristic extraction as determined by knowledge, following von Tunzelmann's interpretation our model can be interpreted as providing, although in an extremely embryonic and stylized way, also a model of a knowledge-based theory of technology. The attention paid here to the determination of production prices and distribution associated to "equilibrium" techniques allows us to describe the evolution of the technology and techniques as driven by knowledge, where the dynamics of the latter is affected by prices and distribution as well.[7] We show in addition that our model is able to deal with intrasectoral heterogeneity of firms. Hence, the paper provides a first contribution to fill in the gap in von Tunzelmann, Dosi and Grazzi's informal analysis by showing that the formalization of von Tunzelmann's view provides an initial step towards a rigorous "procedural" foundation of the input–output representation of technology and the analysis of the evolution of the entire economy with localized technical progress. Given that our model can accommodate issues like heterogeneity of firms and the dynamics of their technologies, our model can be interpreted also as providing a theoretical foundation to the empirical analysis of some of the "stylized facts" carried out in Dosi and Grazzi (2006).

2. Technology

In this section we develop intuitively a characteristic approach to technology which is particularly apt at being integrated within the "procedural" approach proposed by the evolutionary theory. According to this approach a production technique is conceived as being determined by the firm's ability "to do something" (see, e.g. Winter, 1968), or by firm's "deep craft" (Arthur, 2009): specifically, in our case, and paralleling Sen's capability approach, a production technique is conceived as being determined by firm's ability to extract (technical) characteristics from inputs.

Consider a single production economy with n produced goods used as inputs, only one non produced input (labour) indicated by $n+1$, m technical characteristics and F_i firms in industry i, $i \in N = \{1, 2, \ldots, n\}$. Indicate by N_i the index set of firms in industry i. Fig. 1 illustrates intuitively the productive process to produce *one* unit of good i, $i \in N$, by firm i_f, $i_f \in N_i$. The choice variables of firms are the quantities used of the $n+1$ inputs; however, production of the output is assumed to be generated by the amount of *technical* characteristics extracted from the inputs.

Based upon the "procedural" approach to production, the extraction of characteristics is interpreted to be determined by the "rules" that firms follow in using inputs, which are in turn determined by firms' (static and dynamic) "capabilities" (see, e.g. Richardson, 1972; Kogut and Zander, 1992; Teece et al., 1997).

Assumption 2.1. In order to produce y_i units of good i, $y_i \in \mathbb{R}_+$, $i \in N$, it is necessary to use at least $y_i c^i{}_k$ units of

[2] An interesting exception is Auerswald et al. (2000) who consider a simple recipe-based partial equilibrium model of technology and analyze the dynamics of learning by-doing of the relevant firm. Interesting as it may be, this work is carried out within a partial equilibrium approach, so it misses to provide a satisfactory analysis of choice of technique and of (induced) technical change.

[3] See also von Tunzelmann and Wang (2007).

[4] Early works on characteristic-based approaches to production are represented by the literature on engineering approach to production function (see, e.g. Chenery, 1949, 1953; Marsden et al., 1974) and more recent works on technical change like Triplett (1985). This literature, however, has never developed a systematic analysis of this approach and, in particular, has never emphasized the role of knowledge.

[5] In Section 5 we shall see that the characteristic-capability approach can be traced back also to Penrose (1959) and, therefore, it is consistent with the resource-based view of firms.

[6] Lancaster (1966b) considers explicitly the role of knowledge in determining the technology of extraction of characteristics from final goods.

[7] Our axiomatization of von Tunzelmann's approach within the classical approach is carried out only considering the "price side" of the economy. A more complete analysis should include also the "quantity side" of the economy which could naturally be accomplished by using the characteristic approach as usually done in consumer theory. We confine our attention to the price side of the economy for the sake of simplicity and also for the still unsatisfactory state of demand theory in linear production models (for developments taking into account demand and new goods, see D'Agata, 2010).