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The relation between the speed of demand saturation and the dynamism of the labour market

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ABSTRACT

The purpose of this paper is to examine the medium run effect of the speed of demand saturation on the dynamism of the labour market which involves factors such as the growth of employment and real wage rate, using a computer simulation of the stochastically multi-sectoral pure labour model with a logistic demand function. From the simulation, we obtain the evolutions of the expectation of the employment rate and the real wage rate, supposing three cases where the speed of demand saturation for a product that stochastically emerges is, *ceteris paribus*, different. As a result, it is demonstrated that the faster growth of demand for a product that emerges stochastically accelerates the growth of employment, but decelerates the growth of real wage rate. The result depends on the heterogeneity of the agents, which is neglected by mainstream economics.

1. Introduction

The purpose of this paper is to examine the medium run effect of the speed of demand saturation on the dynamism of the labour market by using a computer simulation of the multi-sectoral pure labour model with a logistic demand function. In this paper, the dynamism of the labour market implies the evolutions of employment and real wage rate.

Today, the importance of technical progress as a source of economic growth is undeniable. Therefore, most economists recommend the promotion of technical progress as part of economic policies. The promotion involves not only raising the labour productivity of existing products (process innovation) but also creating new products (product innovation).

Almost all the theories that emphasize the importance of technical progress are based on the supply-side model, following Solow (1956) tradition (Aghion and Howitt, 1992; Lucas, 1988; Romer, 1990, etc.). The point of discussion in such models does not include whether or not there is a demand for the products produced as a result of technical progress. Moreover, many economists try to explain why the dynamism of the labour market has been sombre in advanced economies since the 1980s by using such models (see, for example, Hornstein et al., 2005).[1] On the contrary, there are very few models that focus on the demand side

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[1] The sombreness of the labour market is often termed 'jobless recovery'. The phenomenon that the recovery of employment after recession and the growth in real wage rate relative to that of productivity become weaker are focused on, especially in the U.S. With respect to this phenomenon, it is pointed out that the gains by productivity growth do not spill over to labour income. See, for example, Council of Economic Advisers (2004, chaps. 1, 2), Dew-Becker and Gordon (2005), and Grosben and Potter (2003).

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in discussions on both the economic growth propelled by technical progress and the dynamism of the labour market.

We believe that the demand side still has an importance in macroeconomics. The relative lack of importance of the demand side in mainstream economics is partially on account of the following unrealistic property of the demand function: homothetic preferences. Some economists who are critical to the property often focus on the 'Engel law', the robustness of which is empirically confirmed (see Foellmi, 2005, chaps. 1, 2 in detail), and begin to build models on the basis of non-homothetic preferences.

Pasinetti's (1981, 1993) models are well known among such models. He builds the dynamic macro-models of structural change, based on the classical-Marxian labour theory of value, with a non-homothetic demand function and persistent dispersion of growth rate of productivity across sectors. Since, unlike mainstream economics, the models of structural change are free from *ad hoc* assumptions, there is great scope for further sophistication. For example, Andersen (2001) presents a model to provide Pasinetti's model with an evolutionary microfoundation, which endogenizes the demand and labour coefficients as well as the number of firms. Notarangelo (1999) presents the two-sector model with the specified non-homothetic demand function and persistent dispersion of productivity growth, and investigates the evolution of *technological* unemployment.[2] Reati (1998) attempts to develop the model by introducing technological revolutions in order to endogenize productivity growth. Also, there are empirical investigations on the basis of Pasinetti's model. For example, Hölzl and Reinstaller (2007) confirm that Pasinetti's conjectures regarding the interplay of sectoral employment and output growth with sectoral productivity and demand growth are well supported by the data about Austrian manufacturing sectors.

Baumol (1967) builds the pure labour two-sector model of structural change similar to that of Pasinetti. While Baumol assumes the constant *relative* outlay and outputs instead of explicitly assuming demand functions, the assumption of the non-homotheticity of preferences is certainly included in Baumol's model as well.[3] An important characteristic of Baumol's model is, as indicated by Notarangelo (1999, p. 210), that it focuses only on *relative* magnitudes, and then, unlike Pasinetti's model, it does not provide any indications regarding the implications for absolute magnitudes—particularly aggregate employment. Baumol's model is also applied to a large number of interesting topics. For example, Rowthorn and Ramaswamy (1997) build a three-sector model on the basis of Baumol's model in order to explain de-industrialization. Raiser et al. (2004) build a three-sector model on the basis of Rowthorn and Ramaswamy (1997) for analysing the structural change that has arisen in the transitional economy. Sasaki (2007) investigates the special case of Baumol's model – that the service sector plays a role in both intermediate and final consumption – and concludes that the share of employment in manufacturing and growth rate decline in the long run, irrespective of the size of the elasticity of substitution between labour and service input.

Furthermore, there are literatures from the theoretical scheme that are closer to the mainstream viewpoint. Echevarria (1997) builds a model with non-homothetic preferences and derives the result that sectoral composition affects growth rate under the assumption that each consumption good is produced by different factor intensities and rates of technological change. Furthermore, Echevarria (2000) builds a three-sector model with non-homothetic preferences on the basis of Solow's model where capital intensities are different and indicate, as opposed to the result derived from Solow's model, the positive correlation between the growth rates and levels of income in both a closed and open economy. Laitner (2000) builds a model with non-homothetic preferences and indicates that the structural change caused by preferences endogenously determines the national saving rate, as opposed to the usual causality. Kongsamut et al. (2001) build a three-sector model with the non-homothetic demand function using the Geary-Stone utility function and indicate that balanced growth is not inconsistent with structural change. Matsuyama (1992, 2000) applies the non-homothetic demand function to the determination of comparative advantage. Foellmi (2005) builds the endogenous growth model with the hierarchic and non-homothetic demand function and analyses the relationship between inequality and demand structure. Finally, Aoki and Yoshikawa (2007, chap. 8) build a growth model with the non-homothetic demand function, using the continuous-time Markov process in which there is a stochastic emergence of a new commodity that stimulates demand, and show that growth rate declines because of the saturation of demand.

As is evident from the above survey of existing literatures on the growth model that emphasizes the importance of the non-homotheticity of preferences, there are very few literatures that analyses the relationship between *aggregate* employment, non-homothetic preferences, and productivity growth.[4] A majority of the analyses on structural change, such as Baumol, irrespective of whether or not they depend on the mainstream viewpoint, are related to *relative* magnitudes—relative share of employment, output, etc. However, *aggregate* variables such as employment and output are the most important economic variables, as shown by the principle of effective demand given by Keynes (Keynes, 1973, chap. 3).

Focusing on the relationship between *aggregate* employment, non-homothetic preferences, and growth rates of productivity has become increasingly important. While productivity growth has become faster due to the advent of IT in the US economy, as is already mentioned, the dynamics of the labour market has been sombre. Dew-Becker and Gordon (2005) indicate the recent failure of productivity gains to spill over to labour income. Therefore, it is

[2] See Pasinetti (1981, pp. 88–90) and Pasinetti (1993, pp. 53–55) with regard to the notion of technological unemployment.

[3] See Gundlach (1994) in detail.

[4] The exceptions are Hölzl and Reinstaller (2007) and Notarangelo (1999), both of which are based on Pasinetti's model.

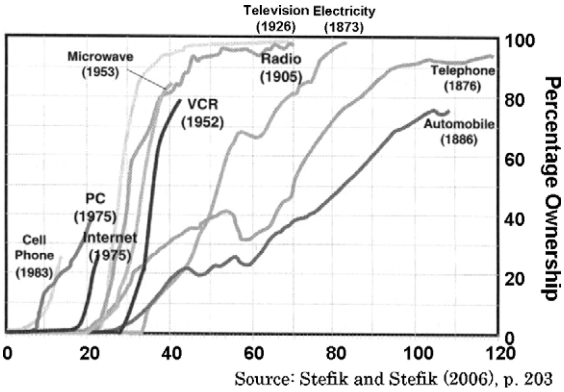

Fig. 1. Year of introduction of various consumption goods in the U.S.

important to examine the relationship between productivity growth and the dynamism of the labour market.

For this purpose, we use the multi-sectoral pure labour model on the basis of Pasinetti (1993) with the stochastic product innovation. This is because Pasinetti's model can analyse the evolution of *aggregate* employment, output and real wage rate. The assumption of the pure labour model is obviously simplified, since capital does not appear explicitly. However, there are reasons to justify this. The pure labour model is 'a minimal theoretical scheme that allows the representation of almost all the basic characteristics of the structural dynamics of a production economic system' (Pasinetti, 1993, p. 15). In other words, it offers all the ingredients to pursue the object of this paper (i.e. the relation between the dynamics of productivity, aggregate employment and real wage rate) without missing the essential aspects of real economies.

In order to explain the contemporary sombreness of the labour market in advanced economies, unlike in mainstream economics, we examine the effect of the demand side on the dynamism of the labour market. In particular, we focus on the contemporary tendency of demand growth that recently emerged products diffuse much faster than the radically innovative consumption goods of the past, such as automobiles, televisions, and telephones. Fig. 1 illustrates this tendency.

According to Stefik and Stefik (2006, p. 204), an advantage of the faster diffusion of recent technologies is that they reuse the infrastructure pioneered by older technologies. It is interesting to examine the relation between the tendency of faster diffusion of the recent emerged products and the evolutions of the aggregate employment and real wage rate.

In fact, the pure labour model is a favourable assumption when we focus on such a tendency. The pure labour model is the normative model (i.e. the *natural* economic system[5]) of the post-Keynesian production model, which is independent of any institutions, behavioural rules, and organizations. The relevance of the *natural* economic system is to provide us with the indication for institutional blueprints.[6] Since the *actual* labour markets are institutions (see, for example, Amable, 2003), the effect of speed of demand saturation on the dynamism of the labour market would be different among the economic systems, depending on what kind of institution of the labour market is set up.[7] The pure labour model allows us to extract the pure effect of speed of demand saturation, which is not affected by institutions, behavioural rules, and organizations, on the dynamism of the labour market.

This paper is organized as follows. Section 2 recalls the essence of Pasinetti's (1993) model. Section 3 specifies the logistic demand function and presents the stochastic model used in the computer simulation, as a result of which we obtain the evolutions of expectation of the employment rate and real wage rate. In this section, the implication of the simulation results is also demonstrated. Finally, Section 4 presents the conclusion.

2. Revisiting the Pasinetti model

To begin with, we recall the essence of Pasinetti's (1993) model. It is a multi-sectoral pure labour model. We suppose an economy wherein the division of labour and market specialization are well developed. Each individual produces or contributes to the production only one kind of product. This immediately implies that individuals in the economy necessarily exchange goods and services, including labour, in markets. Workers thus increase the labour productivity.

Suppose that the physical output, the employment required by the ith sector, the total population are denoted by Q_i, L_i, and N, respectively. Then, the labour coefficient of the ith sector is defined as $l_i \equiv L_i/Q_i$ $(i = 1, 2, \ldots, M)$, where $M \geq 2$ is the number of sectors. The evolution is expressed by $l_i(t) = l_i(0)\mathrm{e}^{-\rho_i t}$, where $\rho_i > 0$ and $l_i(0) > 0$ are the growth rate of productivity and the initial value of the labour coefficient of the ith sector respectively. On the contrary, the per-capita consumption coefficient of the ith sector is defined as $c_i \equiv Q_i/N$. The evolution is expressed by $c_i(t) = c_i(0)\mathrm{e}^{r_i t}$, where $r_i > 0$ and $c_i(0) > 0$ are the growth rate of per-capita consumption and the initial value of per-capita consumption of a product produced by the ith sector, respectively. Then, we obtain the $M+1$ order systems of price and quantity equations.

$$\begin{cases} p_i(t) = l_i(t)w(t) \qquad i = 1, 2 \cdots, M \\ \displaystyle\sum_{i=1}^{M} p_i(t)c_i(t) = w(t) \end{cases}, \tag{1}$$

[5] See Pasinetti (2007, pp. 279–304) concerning the *natural* economic system.

[6] Pasinetti (2007, pp. 274–279) calls the methodological distinction between the *natural* stage of investigation and the institutional stage 'separation theorem'.

[7] Blanchard and Wolfers (2000) investigate the effect of labour market institution absorbing various shocks on the evolution of employment, and conclude that the institutional differences can persuasively explain the evolution of European unemployment both over time and across countries. Also, Bertola et al. (2001) confirm the similar institutional effect on the U.S. labour market.

$$\begin{cases} Q_i(t) = c_i(t)N(t) \qquad i = 1, 2, \cdots, M \\ \displaystyle\sum_{i=1}^{M} Q_i(t)l_i(t) = L(t) \end{cases}, \tag{2}$$

where p_i and w denote the price of the product produced by the ith sector, the uniform nominal wage rate, respectively. The systems of Eqs. (1) and (2) demonstrate that prices and quantities are determined by the embodied labour theory of value and the principle of effective demand, respectively. The condition for the non-trivial solution of the above systems is the same:

$$\sum_{i=1}^{M} c_i(t)l_i(t) = \sum_{i=1}^{M} c_i(0)l_i(0)\,e^{(r_i-\rho_i)t} = 1.$$

This is a condition for the achievement of full employment. The term $c_i(t)l_i(t)$ can be interpreted in two ways. According to system (1), it denotes the proportion of the potential national income generated in the ith sector by the effective demand. On the contrary, according to system (2), it denotes the proportion of the overall employment required by the ith sector. The most fundamental feature that distinguishes Pasinetti's model from the mainstream balanced growth models is the assumption of $r_i \neq \rho_i$ for all $i = 1, 2, \ldots, M$. Moreover, the above condition implies that the achievement of full employment is not a problem to be addressed only once, but continually (Pasinetti, 1993, pp. 53–57).

In order to focus on unemployment, we introduce another parameter: $\mu(t) \equiv L(t)/N(t) = \sum L_i(t)/N(t)$. In other words, μ is the employment rate. Furthermore, we assume that the total population grows at an exogenous rate, $g > 0$: $N(t) = N(0)\,e^{gt}$. Therefore, the above condition is rewritten as follows:

$$\sum_{i=1}^{M} c_i(t)l_i(t) = \mu(t) \quad \text{or} \quad \frac{1}{\mu(t)}\sum_{i=1}^{M} c_i(t)l_i(t) = 1. \tag{3}$$

The *natural* wage rate is the one obtained when condition (3) is held in system (1). It can be summarized as follows: 'its *real* content is given by the basket of physical commodities that on average it can purchase. The natural wage rate thus expresses a synthesis of the characteristics of technology and of the characteristics of consumption choices of the economic system considered as a whole' (Pasinetti, 1993, p. 24).

As is well known, the above $M+1$ order linear systems of equations have only M independent equations in each system. Therefore, we must select the *numéraire* in order to close the systems. In system (2), $N(t)$ is naturally selected. In system (1), a composite commodity known as the 'dynamic standard commodity', whose productivity grows at the *standard* rate, is introduced. The standard rate of growth of productivity, $\rho^*(t)$, is defined as follows:

$$\rho^*(t) = \sum_{i=1}^{M} \eta_i(t)\rho_i, \tag{4}$$

where the weight coefficient is defined as follows: $\eta_i(t) \equiv (1/\mu(t))c_i(t)l_i(t)$. Note that formula (4) is the weighted average of the growth rates of the productivity of the entire economic system because it follows that $\sum_{i=1}^{M}\eta_i(t) = 1$. As is clear from condition (3), the weight coefficient denotes the proportion of employment required in the ith sector to the total employment.

Then, system (1) is closed by selecting the *natural* wage rate measured by the dynamic standard commodity as *numéraire*, which is expressed as follows:

$$w^*(t) = \bar{w}^*(0)\,e^{\rho^*(t)t}, \tag{5}$$

where $\bar{w}^*(0)$ denotes the initial value of the *natural* wage rate measured by the dynamic standard commodity. The *natural* wage rate is regarded as the most straightforward and convenient form of the wage rate because $\rho^*(t)$ implies the growth rate of the *real* wage rate. This is because selecting the *natural* wage rate as the *numéraire* of the price system keeps the general price level constant over time.[8]

In the pure labour model, the entire national income is distributed as wages; the per-capita national income measured by the dynamic standard commodity, $y^*(t)$, is equal to the *natural* wage rate measured by the dynamic standard commodity multiplied by the employment rate:

$$y^*(t) = \mu(t)w^*(t) = \bar{w}^*(0)\mu(t)\,e^{\rho^*(t)t}.$$

The evolution of the per-capita national income measured by the dynamic standard commodity depends on that of μ and ρ^*.

3. Simulation in the stochastic Pasinetti model

In this section, we present the stochastic Pasinetti model by combining the Pasinetti model reviewed in Section 2 with a stochastic process termed as a continuous-time Markov chain. Subsequently, we analyse the simulation of the stochastic model in order to examine the effect of the speed of demand saturation on the dynamism of the labour market. Moreover, we present the simulation results and discuss their implications.

3.1. Specification of the demand function

First of all, we need to specify a non-homothetic demand function used in the stochastic model. A typical demand function that contains non-homotheticity, often used in economics, is the logistic function (see, for example, Andersen, 1994; Aoki and Yoshikawa, 2007; Notarangelo, 1999):

$$c(t) = \frac{K}{1 + ((K - c(0))/Kc(0))\,e^{-Krt}}, \tag{6}$$

where $K > 0$, $c(0) > 0$, and $r > 0$ denote the carrying capacity, the initial value of the consumption coefficient, and the parameter defining the growth rate, respectively. In what follows, for simplicity, we use the notation $\alpha \equiv (K - c(0))/Kc(0) > 0$.

[8] See Pasinetti (1981, pp. 136–138) with regard to the conceptual differences between the *natural* wage rate and the *real* wage rate determined by the marginal productivity of labour.

The saturation point is determined by the value of K (the asymptote of the logistic function) while the speed of the demand saturation depends on the demand growth (i.e. r)—the higher the value of r the faster the saturation point is reached.

3.2. *The model*

The stochastic Pasinetti model assumes that the emergence of a new product (product innovation) occurs stochastically according to a continuous-time Markov chain, termed as the Yule process. In other words, the product innovation assumed here is the stochastic increase in the number of sectors (i.e. products) by a pure birth process with the birth rate λ. According to the Yule process, the probability of the emergence of a product at the given interval depends on the number of products that already exist. Let us define the number of products at period t as $M(t)$. Accordingly, the probability that a new product will emerge at the interval $(t,\ t+\Delta t)$ is expressed by $\lambda M\,\Delta t$. This assumption is often used in economics. Although it is a simplification, it is plausible at least in the medium run; this is because, as Aoki and Yoshikawa (2007, p. 226) point out, product innovation is a 'branch off' of the existing sectors.

Let us suppose that $P_m(t) \equiv P[M(t)=m]$ denotes the probability that the number of products at period t is m. The probability that the number of existing products is m at period t and $(m+1)$th product emerges at interval $(t, t+\Delta t)$ is then given by the following[9]:

$$\lambda m P_m(t)\,\Delta t = \lambda m e^{-\lambda t}(1-\mathrm{e}^{-\lambda t})^{m-1}\,\Delta t. \tag{7}$$

Furthermore, we include the assumption on the growth of productivity and demand for a newly emerged product. With regard to the former, according to the function defined below, the productivity of both the sector existing at period 0 and those that stochastically emerge is assumed to increase over time. This implies that all sectors are competitive, and process innovation also occurs once the product emerges. In other words, both product innovation and process innovation arise in our model. With regard to the latter, we assume that the more the emergence of a newly product is delayed, the more the speed of the demand saturation for the product increases. It is nothing but the situation illustrated by Fig. 1. Finally, the initial values concerning the stochastically emerged product and the parameters are determined as follows: $K=20$, $c(0)=0.008$, $l(0)=0.085$, and $\lambda=0.002$. The first three values of parameters are the same, irrespective of when a sector emerges according to the Yule process.

From a set of assumptions on the growth of productivity, the growth rate of productivity of a product that emerges at period τ increases at period $t(t>\tau)$.[10] Let us denote this as $\rho_{t-\tau}$. Therefore, the labour coefficient of the sector that emerges at period τ evolves at period t as follows: $l(t-\tau)=l(0)\,\mathrm{e}^{-\rho_{t-\tau}(t-\tau)}$. On the other hand, from a set of assumptions on the growth of demand, the parameter defining the growth rate of demand for the product that emerged at period τ is expressed by r_τ. This parameter does not evolve over time. According to the logistic demand function (6), the evolution of the consumption coefficient is then expressed as $c(t-\tau)=K/(1+\alpha e^{-r_\tau K(t-\tau)})$.

Therefore, we obtain the expectation of the employment rate from formulas (3) and (7) as follows:

$$\begin{aligned} E[\mu(t)] &= \sum_{m=1}^{\infty}\int_0^t \lambda m\,\mathrm{e}^{-\lambda\tau}(1-\mathrm{e}^{-\lambda\tau})^{m-1}c(t-\tau)l(t-\tau)\,\mathrm{d}\tau + c(t)l(t) \\ &= \lambda\int_0^t \mathrm{e}^{\lambda\tau}\frac{l(0)K\,\mathrm{e}^{-\rho_{t-\tau}(t-\tau)}}{1+\alpha\,\mathrm{e}^{-r_\tau K(t-\tau)}}\,\mathrm{d}\tau + \frac{l(0)K\,\mathrm{e}^{-\rho_0 t}}{1+\alpha\,\mathrm{e}^{-r_0 Kt}} \end{aligned}, \tag{8}$$

where r_0, ρ_0, and E denote the parameter indicating the growth rate of demand for the product of the sector existing at period 0, the productivity growth rate of the sector existing at period 0, and the expectation, respectively.[11] The second term of the right-hand side of function (8) denotes the evolution of the employment rate of the sector existing at period 0. Applying the same procedure to formula (4), we obtain the expectation of the standard rate of the growth of productivity:

$$E[\rho^*(t)] = \frac{\displaystyle\int_0^t \mathrm{e}^{\lambda\tau}(l(0)K\,\mathrm{e}^{-\rho_{t-\tau}(t-\tau)}/\ (1+\alpha\,\mathrm{e}^{-Kr_\tau(t-\tau)}))\,\rho_{t-\tau}\,\mathrm{d}\tau}{\displaystyle\int_0^t \mathrm{e}^{\lambda\tau}(l(0)K\,\mathrm{e}^{-\rho_{t-\tau}(t-\tau)}/\ (1+\alpha\,\mathrm{e}^{-Kr_\tau(t-\tau)}))\,\mathrm{d}\tau}. \tag{9}$$

3.3. *Simulation*

By using functions (8) and (9), we compare the evolutions of the expectation of the employment rate and real wage rate when the speed of demand saturation, *ceteris paribus*, is different. Recall that the differences in the speed, as demonstrated in Section 3.1, are given by those in r of function (6). Let us suppose three cases of the parameter r_τ as follows. We suppose the function of the growth rate of productivity $\rho_{t-\tau}$.

[Case 1: The benchmark case]

The forms of function of $\rho_{t-\tau}$ and r_τ are assumed as follows:

$$\rho_{t-\tau} = 0.015 + 0.0009(t-\tau), \tag{10}$$

$$r^*_\tau = 0.01 + 0.00035\tau, \tag{11}$$

where r^*_τ denotes r_τ in the benchmark case. The functions imply the linear growth of productivity and parameter defining the growth rate of demand. They seem to be less

[9] See, for example, Taylor and Karlin (1998) pp. 339–340.

[10] Hereafter, we omit the subscript i indicating a sector. This is because, in the stochastic process of our model, the characteristic of a sector is given by the period when it emerges: $c(t)$, $c(t-1)$, $c(t-2)$, ..., and $l(t)$, $l(t-1)$, $l(t-2)$, ... etc.

[11] It would be redundant to demonstrate the procedure for deriving function (8). See Aoki and Yoshikawa (2007, p. 228) wherein the procedures similar to our model are explored.

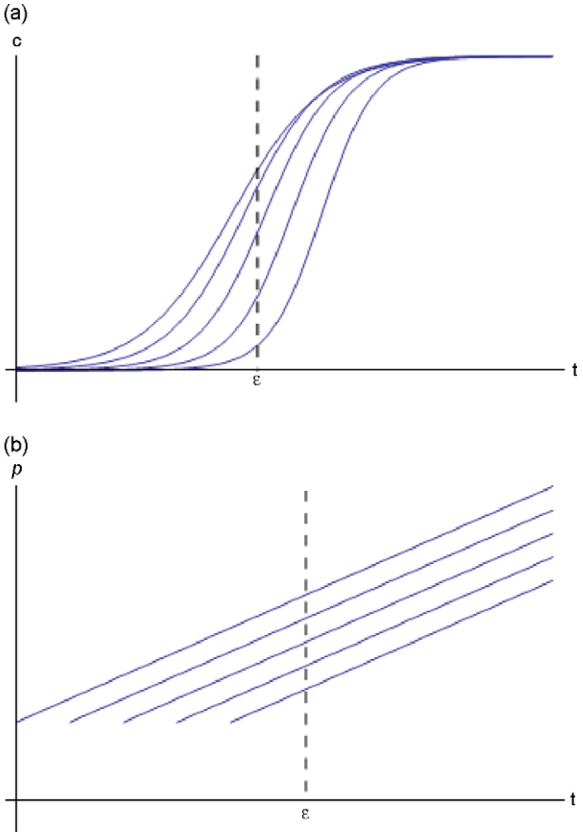

Fig. 2. (a) The dispersion of per-capita consumption coefficient at period ε. (b) The dispersion of productivity growth rate at period ε.

restrictive assumptions in a comparison with the mainstream growth model. They imply that it gradually takes longer for the growth rate of productivity of the product that emerges at period τ to outpace the growth rate of demand for the product, as it emerges later. In order to focus on the effect of only the demand side, the supply-side condition indicated by function (10) is assumed to be the same in all cases.

Furthermore, it must be noted that functions (10) and (11) imply that there is a disparity in the growth rates of both productivity and demand across sectors at the arbitrary period ε, as shown in Fig. 2a and b.

Fig. 2a illustrates the growth of the consumption coefficient of the product that, as examples, emerges at $\tau = 0$, 5, 10, 15, and 20 under function (11): $c(t)$, $c(t-5)$, $c(t-10)$, $c(t-15)$, $c(t-20)$. Fig. 2b illustrates the growth of productivity according to function (10) under the same assumption as in Fig. 2a: ρ_0, ρ_{t-5}, ρ_{t-10}, ρ_{t-15}, ρ_{t-20}. The figures indicate that our model includes the heterogeneity, which refers to the disparity of the growth rates of productivity and demand.[12]

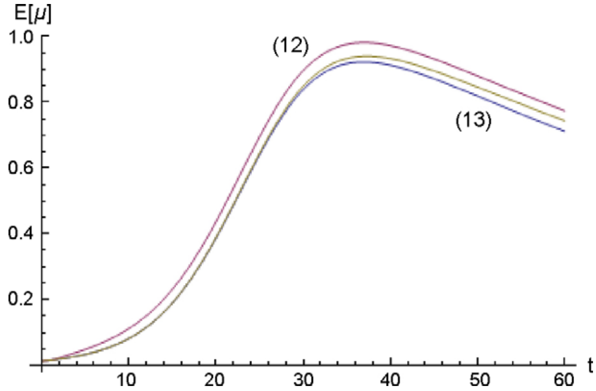

Fig. 3. The evolution of employment rate.

[Case 2: The higher demand growth case]

In this case, the function defining the growth rate of demand, denoted by r_τ^+, is assumed as follows:

$$r_\tau^+ = 0.01 + 0.35\tau. \tag{12}$$

In this case, the demand for products that stochastically emerge saturates faster than the benchmark case.

[Case 3: The slower demand growth case]

The function defining the growth rate of demand in this case, which is denoted by r_τ^-, is assumed as follows:

$$r_\tau^- = 0.01 + 0\tau. \tag{13}$$

Since the parameter defining the growth rate is independent of τ, the consumption coefficient follows the same evolution, irrespective of when the product emerges. Furthermore, in this case, the demand for the products that stochastically emerge saturates slower than in the benchmark case.

In other words, the following inequality is held with regard to the parameters defining the growth rate of demand: $r_\tau^+ \geq r_\tau^* \geq r_\tau^-$ for $^\forall\tau$.

3.4. Results of the simulation

The evolutions of the expectation of the employment rate in the above three cases, obtained by function (8), are presented in Fig. 3. The upper portion of the figure displays a curve in the case of (12), that is, the fastest demand growth case, and the lower portion displays a curve in the case of (13), that is, the slowest demand growth case. The middle portion displays a curve in the benchmark case. Fig. 3 shows that the expectation of employment rate in all the cases increase and subsequently decrease.

Although the differences between the cases in terms of the growth of employment rate are initially small, they become larger in the medium run. The extent of increase in the growth of employment rate is the largest in the case of (12) and smallest in the case of (13). In other words, the

[12] The original model of Pasinetti (1993) also includes the heterogeneity. However, there is a difference between the original model and our stochastic model with respect to the emergence of the heterogeneity. The former assumes the disparity of the growth rate of demand and productivity and further assumes the differences in the initial values of both the consumption and labour coefficients. On the contrary, the latter assumes that the initial values are equal in all cases and that the growth rates of productivity and demand follow the same function in each case, as is shown later in detail. The heterogeneity in the latter is a result of the difference in the period when the sector emerges.

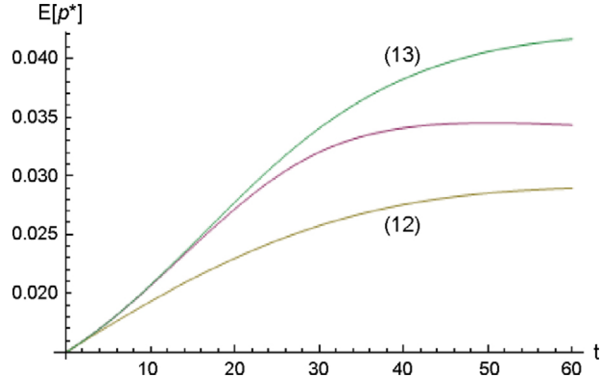

Fig. 4. The evolution of the standard rate of growth of productivity.

emergence of a new product does accelerate the growth of employment rate. However, the extent of the acceleration depends on the speed of demand saturation for the new product. It is revealed that if the supply-side conditions are the same, the faster the speed of demand saturation for a newly emerged product is, the larger is the extent of acceleration of the growth of employment rate in the medium run. From the viewpoint of the growth of employment rate, it is desirable to increase the number of products whose demand saturates faster.

The evolutions of the expectation of the standard rate of growth of productivity in the above three cases, obtained by function (9), are illustrated in Fig. 4. The evolutions have convergences in all cases. It is evident that $\lim_{t\to\infty} E\left[(\mathrm{d}\rho^*(t)/\mathrm{d}t)/\rho^*(t)\right] = 0$ because of the nature of the Yule process, irrespective of the specification of the function of $\rho_{t-\tau}$ and r_τ. The upper portion of Fig. 4 is the curve in the case of (13), and the lower portion is that in the case of (12). The middle portion is the curve indicates the benchmark case. Although, as in Fig. 3, the differences in the growth of the real wage rate are initially small, they become larger over time. The case of (13) has the highest convergence of the growth rate of the real wage rate, and the case of (12) has the lowest convergence. In other words, if the supply-side conditions are the same, the faster the speed of demand saturation for a newly emerged product is, the smaller is the extent of the growth of real wage.

We shall now explore why such results are obtained. According to the difference in parameter r_τ, we can obtain such a relation of the consumption coefficient as follows: $K/(1+\alpha\,\mathrm{Exp}[-r_\tau^+ K(t-\tau)]) \geq K/(1+\alpha\,\mathrm{Exp}[-r_\tau^* K(t-\tau)]) \geq K/(1+\alpha\,\mathrm{Exp}[-r_\tau^- K(t-\tau)])$for $^\forall\tau$. The relation implies that since the supply-side conditions are the same in all cases, the area integrated according as function (8) becomes larger as the speed of demand saturation is faster. Since, therefore, the term $c(t-\tau)l(t-\tau)$ in function (8) denotes the proportion of the employment at period t required by the sector that emerges at period τ, the extent of the acceleration of the employment rate is increased more by the faster speed of demand saturation than the slower speed of demand saturation. This is a positive effect of the stochastic emergence of a product on aggregate employment. However, there is another effect on the employment, which is caused by the sector existing at period 0. As already mentioned, it is shown by the second term of the right-hand side of function (8). This effect is initially positive. The proportion of employment required by the sector increases while demand for the product produced by the sector grows. According to the assumption of the logistic demand function, however, the demand growth ultimately comes to an end. At this time, the negative effect by the sector begins to work. When the negative effect becomes larger, the expectation of the employment rate begins to decrease.[13]

On the other hand, the faster speed of demand saturation implies that the weight coefficient of the standard rate of growth of productivity, which corresponds to $\eta_i(t)$ in formula (4), *ceteris paribus*, begins to decrease earlier. As is already mentioned, the weight coefficient is the proportion of the employment in each sector to the total employment. Therefore, it begins to decrease earlier when the speed of demand saturation is faster, irrespective of whatever assumptions are imposed on the growth rate of productivity. This is because a faster speed of demand saturation implies the earlier end of the growth of effective demand, irrespective of the assumption on the productivity growth. The standard rate of growth of productivity is the weighted average, and the extent of its increase is, *ceteris paribus*, smaller when the speed of demand saturation is faster.

We can also explain, more intuitively, the result on the evolution of the expectation of the real wage rate. The real wage rate in our model is the *natural* wage rate defined by formula (5). As is already mentioned, it is measured by the dynamic standard product that maintains the general price at a constant level. Therefore, an increase or decrease in the *natural* wage rate is equivalent to that in the nominal wage rate. Nominal wage is not only a part of the cost of production but also a large part of the purchasing power. This implies that the nominal wage rate can continue to increase while the demand for products is increasing. This is because increasing the nominal wage rate stimulates effective demand. Then, the nominal wage rate cannot increase persistently if the demand is saturated rapidly. This is nothing but a direct implication of the principle of effective demand.

4. Concluding remarks

In order to focus on the importance of effective demand in macroeconomics, we build a stochastic model based on Pasinetti (1993) with a logistic demand function. It is a heterogeneous agent model, unlike the mainstream economic model. Using a computer simulation, we obtain the evolutions of the expectation of employment rate and real wage rate, supposing three cases where the growth rates of demand for a product that stochastically emerges are, *ceteris paribus*, different. The results obtained from the simulation are summarised as follows: the faster growth of demand for a product that emerges stochastically accelerates the growth of employment rate, but decelerates the standard rate of growth of productivity (i.e. the growth of

[13] See the appendix in detail.

real wage rate). The results are direct implications of the principle of effective demand.

The results obtained in the simulation appear to be anomalies in mainstream economics. This is because the extent of the growth of real wage rate is lowest in the case in which the extent of the growth rate of employment is largest. In mainstream economics, according to the theory of marginal productivity, it is natural that the largest improvement in the growth of employment leads to the largest growth in the real wage rate. A significant implication of real wage rate in a capitalist economy where the division of labour is well developed is not given by what happens in the corresponding sector, as supposed in the theory of marginal productivity, but by the relationship between the corresponding and *other* sectors (Pasinetti, 1981, pp. 136–137). The *natural* wage rate is a more fruitful concept. Accordingly, the dynamic relationship between employment and real wage rate is not as simple as to enable a description of the downward-sloping labour demand function and the upward-sloping labour supply function. It is determined by the complex interaction of heterogeneous agents, as demonstrated by Eqs. (4) and (9).

Furthermore, note that the probability of the emergence of a new commodity is the same from the case 1 to case 3: $\lambda = 0.002$. The growth rate of productivity is also the same in all cases of the simulation. Therefore, the supply-side condition in all cases is equivalent. Even though the supply-side condition is the same, the differences in the macroeconomic performance are generated in the case of the non-homothetic preferences. The conclusion cannot be derived from the mainstream economics whose model includes only the representative agent that has the homothetic preferences. Raising productivity and increasing the speed of the product cycle, which are economic policies for growth recommended by mainstream economics, do not necessarily lead to favourable outcomes for macroeconomic conditions under such realistic assumptions as non-homotheticity of preferences and heterogeneity of agents.

Our results of the simulation imply that we may have to endure such a low quality growth where an increase in the real wage rate is miniscule relative to that in employment, depending on the demand side conditions. In fact, such a circumstance has recently been witnessed in advanced economies, for example, in Japan since 2002 and in the 'new economy' era of the U.S. (see Ministry of Health, Labour and Welfare, 2007; Willis and Wroblewski, 2007). In addition, Kliesen (2007) indicates that employment is no longer a useful indicator of output growth. Our results of the simulation may be indicative of the phenomenon.

The demand side conditions are still significant for macroeconomic performance. In addition, the significance is twofold: one is that the *quantity* of demand matters (i.e. the number of sectors in our context) and the other is that the *speed* of demand saturation is also significant.

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Appendix A. The form of function (8)

Let us examine the form of function (8). For the sake of simplicity, let us denote the term $c(t-\tau)l(t-\tau)$ by $\xi(t-\tau)$. Therefore, $\xi(t)$ denotes the proportion of national income produced or the proportion of employment required by the sector existing at period 0: $\xi(t) \equiv c(t)l(t) = (l(0)K\,\mathrm{e}^{-\rho_0 t})/(1+\alpha e^{-r_0 K t})$, where $\rho_0 = 0.015$, $r_0 = 0.01$.

Replacing $t-\tau$ with u and differentiating function (8), we can obtain the following formula by means of the nature of the Yule process:

$$\frac{\mathrm{d}}{\mathrm{d}t}E[\mu(t)] = \lambda \int_0^t \sum_{m=1}^{\infty} \lambda m P_m(\tau+u)\xi(u)\,\mathrm{d}u + \dot{\xi}(t)$$
$$= \lambda E[\mu(t)] + \dot{\xi}(t).$$

Therefore, the form of function (8) depends on the sign of $\lambda E[\mu(t)] + \dot{\xi}(t)$. The first term indicates the effect of the stochastic emergence of the new product on employment, which is always positive. The second term indicates the effect of the sector exiting at period 0 on employment:

$$\dot{\xi}(t) = \frac{l(0)K\,\mathrm{e}^{-\rho_0 t}[(r_0 K - \rho_0)\alpha\,\mathrm{e}^{-r_0 K t} - \rho_0]}{[1+\alpha\,\mathrm{e}^{-r_0 K t}]^2}.$$

Obviously, it follows that $\lim_{t\to\infty}\dot{\xi}(t) = 0$, and the sign of $\dot{\xi}(t)$ solely depends on that of the term of $[(r_0K-\rho_0)\alpha\,\mathrm{e}^{-r_0Kt} - \rho_0]$.

If the value of K is large enough to keep the term of $r_0K - \rho_0$ positive, the sign is positive in the case of $t < t^* = \left\{ t \,|\, \mathrm{e}^{-r_0 K t} = \frac{\rho_0}{(r_0K-\rho_0)\alpha} \right\}$ and it is negative in the case of $t > t^*$, as is shown in Fig. 5.

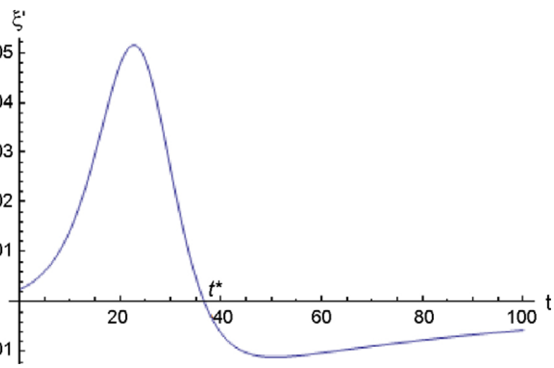

Fig. 5. The function $\dot{\xi}(t)$ in case of $\rho_0 = 0.015$, $r_0 = 0.01$.

In other words, the effect of the sector existing at period 0 turns from positive to negative. The sector existing at period 0 initially has a positive effect on employment while demand for the product produced by the sector is growing. However, according to the logistic demand function defined above, the demand growth comes to an end. It is at this time that the sector existing at period 0 begins to exhibit a negative effect on employment. Accordingly, the expectation of employment rate begins to decrease when the negative effect is large enough to outpace the positive effect by the stochastic emergence of sector, which is always positive.

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