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Demand-led growth and Technological Progress in a Two-sector Cumulative Causation Model

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From the viewpoint of Nicholas Kaldor's cumulative causation theory, this paper describes a theoretical investigation into the effects of increased labor productivity growth on output and employment growth. In the macroeconomic framework used to analyze the mutual interdependence of those variables, productivity growth affects other variables through the wage share. For contrast, we construct a two-sector (namely, the investment goods sector and the consumption goods sector) model with an independent investment function and show that increased productivity growth in one sector raises its own output growth through a change of relative prices. Furthermore, because our two-sector model is sufficiently complicated so that various results are generated depending on the parameters, we apply it econometrically to Japan from the 1980s to the beginning of the 2000s. Results show that rapid productivity growth during the 1990s, especially in the investment goods sector, could have raised its output growth, but in reality the possibility was eliminated by the following factors: the slower trend growth of investment, the sharp decline of exports of investment goods, and the low elasticity of investment with respect to profits in both sectors.

Key words: disproportionate growth, productivity regime, demand regime, cumulative causation
JEL Classification Numbers: E12, O41

1. Introduction

Nicholas Kaldor emphasized that, in order to comprehend economic development mechanisms, both demand and supply side aspects must be considered. He explained that "the process of economic development can be looked upon as the resultant of a continued process of interaction — one could almost say, of a chain-reaction — between demand increases which have been induced by increases in supply, and increases in supply which have been evoked

by increases in demand" (Kaldor, 1972, p. 1246). Although (post) Keynesian economics has attached importance to the "demand-led growth" view (Setterfield, 2002), one must not overlook the effect of improved supply side conditions, such as technological progress or organizational reform, on its demand condition through altering income distribution patterns and price structures.

Kaldor's attractive stance for economic development has been adopted by the French Régulation approach and by recent post-Keynesian research. Boyer (1988) presented the first mathematical model with which to formalize cumulative causation: output (which equals demand) growth has a positive effect on labor productivity growth through Kaldor's concept of the effect of dynamic increasing returns to scale (Kaldor, 1966) or the Verdoorn effect (Verdoorn, 1949); increased labor productivity improves the growth rate of demand through a change of income distribution. The former supply side route (or supply side function) is the so-called productivity regime (hereinafter, PR function); the latter is the demand regime (DR function). By making use of a cumulative causation model, Boyer (1988) and Boyer and Petit (1991) analyzed both the causes of prosperity during the Golden Age and the subsequent stagnation. Following the Boyer model, Naastepad (2006) and Rada and Taylor (2006) presented more elaborate models, which incorporate the mutual relationship among labor productivity, output, employment, and real wage growth. Their models reveal possibilities for establishing diverse growth regimes and show that an increase in real wage growth does not necessarily reduce output and employment growth.

The analytical characteristic common to those studies is that labor productivity growth affects output growth through a change of the wage share. An increase in labor productivity growth reduces the wage share growth rate, because the latter is equal to real wage growth minus labor productivity growth. A decreased wage share, in turn, exerts a positive impact on the growth rate of investment and export, although it negatively affects consumption. If the positive impact is greater than the negative one, then the slope of DR function turns upward on the output growth-labor productivity growth plane (this case is called profit-led), because increased labor productivity growth raises output growth and vice versa. The upward (downward) sloping DR function under the profit-led (wage-led) regime means that real wage growth that is higher than labor productivity growth reduces (raises) output growth. Moreover, if real wage growth is equal to labor productivity growth — in other words, if the wage share is constant — then the slope of the DR function becomes vertical and no shift of the PR function exerts any influence on the output growth rate.

As we examine the real economy, we find that although the wage share shows short-term cyclical fluctuation, its average level in the medium term or long term seems to remain unchanged in some developed countries[1]. For example, the U. S. economy's wage share in 1991 was 65.9% and 65.7% in 2001; its annual growth rate was just −0.03%. The Japanese economy's level was 63.8% in 1991 and 65.7% in 2004; its annual growth rate was only 0.21%. Do these facts imply that the slopes of DR functions are vertical in those countries?

This paper shows that the above-described conclusion is confined to a macroeconomic model. As described herein, by extending a macroeconomic cumulative causation model to a traditional two-sector (namely, the investment goods sector and the consumption goods sector) model, we treat a relative price, rather than the wage share, as a key variable. In our definition, the investment goods sector comprises "Machinery Manufacturing" and "Construction"; the consumer goods sector includes other industries (a detailed method of classification is explained in section 4.1 and the note of Table 1). In our model, the increased labor productivity growth in one sector is related to a decrease of its price relative to another commodity, as formalized in Setterfield (1997) and Uni (2007)[2]. Furthermore, this decrease in the price in one sector relative to another price raises the sector's own output growth, so that the slopes of the DR functions become positive in both sectors on the condition that the wage share remains constant.

Nevertheless, our cumulative causation model does not derive from a strict conclusion, because it includes many parameters. Therefore, we apply it econometrically to the Japanese economy between 1977 and 2003. This empirical task shows that the rapid growth of Japanese labor productivity in the 1990s could have contributed to an increase in output growth in both the investment goods sector and the consumption goods sector; in reality, because of the slower trend growth of investment, the sharp decline of exports of investment goods, and the low elasticity of investment with respect to profits in both sectors, this had a larger negative impact on employment growth and became the main factor that raised the unemployment rate during the period.

This paper is organized as follows. Section 2 presents the construction of the two-sector cumulative causation model. Section 3 explains properties of the DR and the PR functions in both sectors and examines the interrelation between output, labor productivity, and employment growth. Section 4 presents a description of an estimation of the model parameters, using data for Japan between 1977 and 2003; section 5 derives the DR and PR functions in both sectors by substituting parameters into our model. Subsequently, we explain how increased labor productivity affected output and employment growth in Japan's 1990s economy. Section 6 presents concluding remarks.

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[1] In the following calculation, we divide periods as trough-to-trough because the wage share is biased by the business cycle. Data are obtained from *National Income and Product Accounts* (U. S. Department of Commerce, Bureau of Economic Analysis) and *Financial Statements Statistics of Corporations by Industry* (Ministry of Finance, Japan).

[2] We drew a lot of inspiration from Setterfield (1997) and Uni (2007) on the point that labor productivity growth has a positive effect on output growth through the change of relative prices. However, relative price in the Setterfield model is defined as the ratio of domestic price to world price. The Uni model concentrates solely on the cumulative causation process of the investment goods sector and abstracts from the dynamics in the consumer goods sector.

2. Two-sector model

2.1 Productivity regime

Our model assumes that firms in both sectors operate below full capacity. This means that equilibrium of market can be compatible with capacity utilization rate below unity, and full employment is not imposed.

We start from the PR function in the investment sector (sector 1) and in the consumer goods sector (sector 2). Kaldor asserted that dynamic increasing returns to scale exerted their strongest influence on the manufacturing sector. Because many industries, including "Machinery," "Electrical Machinery, Equipment and Supplies," and "Transport Machinery" (which we define as the investment sector), belong to the manufacturing industry, it is natural to presume that a strong effect of dynamic returns to scale exists in the investment goods sector.

$$\hat{\lambda}_1 = \phi_1 + \psi_1 \hat{Y}_1 \tag{1}$$

In that equation, $\lambda_1 (\equiv Y_1/L_1)$ is labor productivity (more accurately stated, a reciprocal of the vertically integrated labor coefficient), Y_1 is the real final demand, and L_1 is employment (the amount of direct and indirect labor)[3] in sector 1. Hereinafter, a variable with a hat sign represents the growth rate of the variable. Equation (1) represents the idea that, through the effect of dynamic increasing returns to scale under $\psi_1 > 0$, the higher the demand for investment goods grows, the greater the labor productivity growth of that sector becomes. In the equation, ϕ_1 denotes the trend of labor productivity growth, and ψ_1 denotes the Verdoorn coefficient in sector 1. These two variables are assumed to be constant.

We maintain that the consumer goods sector is made up of industries that are excluded from the investment goods sector. Although this sector includes such diverse industries as "Agriculture," "Fishing," and "Services," which dynamic increasing returns to scale affect only slightly, it is unrealistic for two reasons to presume that this effect is absent in sector 2. First, this effect depends not only on technological factors but also on institutional factors. For example, Kaldor (1966), in verifying this effect on "Wholesale and Retail Sales," described its cause as production overcapacity, especially excessive labor. Kaldor said, "The productivity of the milkman doubles, without any technological change, when he leaves two bottles of milk outside each door instead of one bottle" (*ibid*, p. 18).

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[3] We can calculate the amount of direct and indirect labor necessary to produce one unit of each commodity, the so-called vertically integrated labor input coefficient (Pasinetti, 1973), and define the growth rate of its reciprocal as labor productivity growth. The vertically integrated labor coefficient is the product of the direct labor input coefficient vector, $\mathbf{L}$, and the Leontief inverse matrix, $(\mathbf{I}-\mathbf{A})^{-1}$, where $\mathbf{I}$ represents the identity matrix and where $\mathbf{A}$ denotes the intermediate input coefficient matrix. Using this method, we obtained the result that the growth rate of labor productivity in "Machinery Manufacturing" was 2.2 percent and that in the consumption goods sector was 0.8 percent in the 1990s.

The effect of dynamic increasing returns to scale always appears unless the amount of employment can be adjusted flexibly to match demand fluctuation, which in turn implies that this effect can be raised (reduced) in an industry with low (high) flexibility of employment. Second, the consumer goods sector includes some manufacturing industries: "Food," "Textiles," and so on. Consequently, we presume an effect on the consumer goods sector overall and formulate the productivity regime function in this sector as

$$\hat{\lambda}_2 = \phi_2 + \psi_2 \hat{Y}_2. \tag{2}$$

Therein, $\lambda_2 (\equiv Y_2/L_2)$ signifies labor productivity (a reciprocal of the vertically integrated labor coefficient), Y_2 represents the real final demand, L_2 denotes employment (the amount of direct and indirect labor), ϕ_2 denotes the constant trend of labor productivity growth, and ψ_2 is the positive Verdoorn coefficient in sector 2.

2. 2 Demand regime

First of all, we briefly present the simultaneous equations system constructing the DR function. Equation (3) describes quantity equation in the investment goods sector, while equation (16) indicates that in the consumer goods sector. Equations (7) and (9) represent the investment function in each sector. Equation (17) shows the consumption function in sector 2. From equation (5), we obtain relative price, which is equal to the investment goods price divided by the consumer goods price. This system, which is composed of six independent equations, has six unknown variables: Y_1 (real final demand in sector 1), Y_2 (real final demand in sector 2), I_1 (investment of sector 1), I_2 (investment of sector 2), C_2 (consumption in sector 2), and p_1/p_2 (relative price). Therefore, our system is closed.

We formulate the aggregate demand of investment goods as

$$p_1 Y_1 = p_1 (I_1 + I_2) + p_1 C_1 + p_1 E_1, \tag{3}$$

where I_1 is the real investment of sector 1, I_2 is the real investment of sector 2, C_1 is the real consumption, E_1 is the real export, and p_1 is the investment goods price. We must include consumption demand in aggregate demand for investment goods, because some investment goods (e.g., electronic appliances and automobiles) are used not only as a means of production by firms but also as a means of consumption by households.

The growth rate of Eq. (3) is the following:

$$\hat{Y}_1 = \Delta_1 \hat{I}_1 + \Delta_2 \hat{I}_2 + \Delta_3 \hat{e}'_1, \tag{4}$$

where $\Delta_1 \equiv \bar{I}_1 / \bar{Y}_1$, $\Delta_2 \equiv \bar{I}_2 / \bar{Y}_1$, $\Delta_3 \equiv 1 - \Delta_1 - \Delta_2$; for convenience, those parameters are assumed to be constant, as in the general cumulative causation

model. In addition, we treat $e_1'(\equiv C_1+E_1)$ as an exogenous variable[4]. Hereinafter, a variable with a bar sign represents the average value of the variable.

Next, we consider the price setting. We adopt the markup pricing rule as presented by Kalecki (1971) and assume that the price of a commodity produced in the i th sector is the product of the markup $m_i\,(>1)$, the nominal wage rate w (which is assumed to be uniform among sectors), and the vertically integrated labor coefficient $1/\lambda_i$[5].

$$p_i=m_i\frac{w}{\lambda_i} \tag{5}$$

The growth rate of Eq. (5) is

$$\hat{p}_i=\hat{m}_i+\hat{w}-\hat{\lambda}_i. \tag{6}$$

For simplicity, the growth rate of markup is assumed to be uniform among sectors. So, we obtain the growth rate of relative price as $\hat{p}_1-\hat{p}_2=\hat{\lambda}_2-\hat{\lambda}_1$.

We further assume that the real investment of sector 1 depends positively on the real profit income of this sector, as formulated in Naastepad (2007):

$$I_1=g_1^{\kappa_1}\Pi_1^{\beta_1}, \tag{7}$$

where $\Pi_1(\equiv(1-\pi_1)Y_1)$ is the real profit, and π_1 is the wage share in sector 1. All of g_1, κ_1, and β_1 are positive constants. Equation (7) can be expressed in terms of the growth rate as

$$\hat{I}_1=\alpha_1+\beta_1\hat{\Pi}_1, \tag{8}$$

where $\alpha_1(\equiv\kappa_1\hat{g}_1)$ is the trend term of the real growth rate of investment, and where β_1 is the elasticity of investment with respect to the profit in sector 1.

Real investment of sector 2 is assumed to be a positive function of nominal profit of this sector divided by the price of the investment goods.

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[4] Following Naastepad (2006) and Rada and Taylor (2006), we can formulate the growth rate of real exports as

$$\hat{e}_i=\eta-\mu\pi_i,$$

where $\hat{e}_i$ is the growth rate of real export demand for the i th good, and where η and μ are positive constants. Although this formulation is apparently meaningful for short-term analyses, it does not remain so for medium-term and long-term analyses, because the average value of the wage share in the long term changes only slightly.

[5] A difference in price formulation exists between the modes of a post-Keynesian setting (Dutt, 1990; Taylor, 1991; Casseti, 2003; Lavoie, 2006) and ours. We use the vertically integrated labor coefficient instead of the direct labor input coefficient because, by adopting "vertical integration," intermediate inputs are reduced to each sector's labor input coefficient, which enables us to abstract a complicated price dynamic.

$$I_2 = g_2^{\kappa_2} \Pi_2^{\beta_2} \tag{9}$$

Therein, $\Pi_2 (\equiv (1-\pi_2) p_2 Y_2 / p_1)$ is equal to the nominal profit income of sector 2 divided by the investment goods price, π_2 is the wage share of this sector, and p_2 is the consumer goods price. Furthermore, g_2, κ_2, and β_2 are positive constants. The growth rate of Eq. (9) is

$$\hat{I}_2 = \alpha_2 + \beta_2 \hat{\Pi}_2. \tag{10}$$

In that equation, $\alpha_2 (\equiv \kappa_2 \hat{g}_2)$ is the trend of the real growth rate of investment of sector 2; β_2 is the elasticity of investment with respect to the profit of this sector.

The profit income in each sector can be expressed in the growth rate as shown below.

$$\hat{\Pi}_1 = -\frac{\pi_1}{1-\pi_1} \hat{\pi}_1 + \hat{Y}_1 \tag{11}$$

$$\hat{\Pi}_2 = -\frac{\pi_2}{1-\pi_2} \hat{\pi}_2 + \hat{Y}_2 + \hat{p}_2 - \hat{p}_1 \tag{12}$$

Here, we assume that each sector's growth rate of the wage share equals zero, as $\hat{\pi}_i = 0$, because, as described above, its average level in the long-term changes only slightly in the real economy. A small change in the growth rate of the wage share has a negligible impact on the demand regime of each sector. After substituting Eqs. (6), (11), (12), and $\hat{\pi}_i = 0$ into Eqs. (8) and (10), the following equations are derived.

$$\hat{I}_1 = \alpha_1 + \beta_1 \hat{Y}_1 \tag{13}$$

$$\hat{I}_2 = \alpha_2 + \beta_2 (\hat{Y}_2 + \hat{\lambda}_1 - \hat{\lambda}_2) \tag{14}$$

Substituting Eqs. (13) and (14) into Eq. (4) engenders the following equations.

$$\hat{Y}_1 = a_1 (\hat{Y}_2 + \hat{\lambda}_1 - \hat{\lambda}_2) + A_1 \tag{15}$$

$$a_1 = \frac{\Delta_2 \beta_2}{1 - \Delta_1 \beta_1}, \quad A_1 = \frac{\Delta_1 \alpha_1 + \Delta_2 \alpha_2 + \Delta_3 \hat{e}'_1}{1 - \Delta_1 \beta_1}$$

Next, we assume that aggregate demand for consumer goods consists of consumption demand, investment demand, and export demand.

$$p_2 Y_2 = p_2 C_2 + p_2 e'_2 \tag{16}$$

In that equation, e'_2 is the sum of real investment and export for consumer goods, and C_2 represents the real consumption demand in sector 2.

$$C_2=(1-s)(p_1Y_1/p_2+Y_2) \tag{17}$$

Therein, s is the constant overall savings rate.

The growth rate of Eq. (16) is expressed as the following:

$$\hat{Y}_2=\theta\hat{C}_2+(1-\theta)\,\hat{e}'_2, \tag{18}$$

where $\theta\equiv\bar{C}_2/\bar{Y}_2$ is assumed to be constant. Using Eq. (6), we obtain the growth rate of Eq. (17) as shown below.

$$\hat{C}_2=\sigma(\hat{Y}_1+\hat{\lambda}_2-\hat{\lambda}_1)+(1-\sigma)\hat{Y}_2-\frac{\bar{s}}{1-\bar{s}}\hat{s} \tag{19}$$

Therein, $\sigma(\equiv\bar{p}_1\bar{Y}_1/(\bar{p}_1\bar{Y}_1+\bar{p}_2\bar{Y}_2))$ is the ratio of average sectoral demand and is assumed to be constant. Substituting Eq. (19) into Eq. (18) yields

$$\hat{Y}_2=a_2(\hat{Y}_1-\hat{\lambda}_1+\hat{\lambda}_2)+A_2 \tag{20}$$

$$a_2=\frac{\theta\sigma}{1-\theta(1-\sigma)},\quad A_2=\frac{1}{1-\theta(1-\sigma)}\left[(1-\theta)\hat{e}'_2-\frac{\theta\bar{s}}{1-\bar{s}}\hat{s}\right].$$

In our two-sector cumulative causation model consisting of Eqs. (1), (2), (15), and (20), unknown variables are $\hat{Y}_1$, $\hat{\lambda}_1$, $\hat{Y}_2$, and $\hat{\lambda}_2$.

3. Properties of the DR and PR functions

3.1 Cumulative causation in the investment goods sector

The slope of the PR function represented by Eq. (1) in the investment goods sector is positive in the (Y_1, λ_1) plane.

The DR function of sector 1 can be derived from Eqs. (2), (15), and (20) as follows.

$$\hat{Y}_1=B_1\hat{\lambda}_1+D_{11}+D_{12}+D_{13} \tag{21}$$

$$B_1=\frac{a_1(1-a_2)}{1-a_2[a_1(1-\psi_2)+\psi_2]},\quad D_{11}=\frac{(1-a_2\psi_2)A_1}{1-a_2[a_1(1-\psi_2)+\psi_2]}$$

$$D_{12}=\frac{a_1(1-\psi_2)A_2}{1-a_2[a_1(1-\psi_2)+\psi_2]},\quad D_{13}=-\frac{a_1(1-a_2)\phi_2}{1-a_2[a_1(1-\psi_2)+\psi_2]}$$

For those expressions, we assume $1-a_2[a_1(1-\psi_2)+\psi_2]>0$. This assumption is valid for the estimated result described in the next section[6].

The slope of the DR function of sector 1, $(1/B_1)$, is positive in the (Y_1, λ_1) plane, which can be easily confirmed by $a_2<1$ (note $\theta<1$ and $\sigma<1$), under the

constant wage share. This conclusion differs greatly from those of macroeconomic models by the likes of Boyer (1988), Naastepad (2006) and Rada and Taylor (2006), but it is similar to those of Setterfield (1997) and Uni (2007). The upward sloping of the DR function signifies that a labor productivity increase (the upward shift of the PR function) causes a rise in demand growth. The reason for this is simple: increased labor productivity growth in sector 1 raises real investment growth of the consumption goods sector through a fall in the price of investment goods, which in turn increases demand growth in sector 1.

An intersection of the DR function and Y_1 axis is represented by the sum of D_{11}, D_{12}, and D_{13}. In addition, D_{11} represents the combined effect of the trend term of investment growth, consumption growth, and export growth of the investment goods on demand growth in sector 1. Furthermore, D_{12} is the combined effect of the growth rate of savings rate, investment growth, and export growth of the consumer goods on demand growth in sector 1. Moreover, D_{13} represents the effect of the trend of labor productivity growth in sector 2 on demand growth in sector 1. Although the sign of the sum is ambiguous, we assume that $D_{11}+D_{12}+D_{13}>0$ because $\hat{s}$ and ϕ_2 are presumed to be small.

Figure 1 depicts the DR function (DR_1) and the PR function (PR_1) in sector 1. Demand and productivity growth are determined at an intersection of those functions. In subsequent figures, the dashed line is the 45 degree line, which represents the circumstances in which demand growth equals productivity growth. The difference between demand and productivity growth is the growth rate of employment, which is represented as a bold line on the horizontal axis, $\hat{L}_1$.

Here, we investigate the cause of a decrease in the growth rate of employment in sector 1. Consider the case in which the DR function slope equals unity (DR_1 in Fig. 2). In this case, the growth rate of employment does not change at any arbitrary point at which the DR function and PR function intersect. For example, the growth rate of employment $\hat{L}_1$ (corresponding to an intersection x_1) equals $\hat{L}_1'$ (corresponding to x_1'). Additionally, we consider the case in which the DR function slope is vertical (DR_1' in Fig. 2). Then the upward shift of the PR function decreases employment growth, because it raises the growth rate of labor productivity while leaving demand growth unchanged. These two cases suggest that when the PR function shifts upward, the steeper the slope of the DR function is, and the more employment growth will decrease.

We can point out a sufficient condition by which the DR function slope becomes steep in sector 1. The DR function slope becomes steeper if the elasticity of investment with respect to profit is sufficiently small (small elasticity implies that the investment is independent of profit). The elasticity of the investment with respect to profit correlates positively with a_1 : $\partial a_1/\partial\beta_1>0$ and $\partial a_1/\partial\beta_2>0$.

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[6] A case of $1-a_2[a_1(1-\phi_2)+\phi_2]<0$ implies that larger A_1 with strong trend term of investment growth or investment goods export growth reduces aggregate demand growth in sector 1. Therefore, based upon both empirical data and logical consistency, it is natural to presume $1-a_2[a_1(1-\phi_2)+\phi_2]>0$.

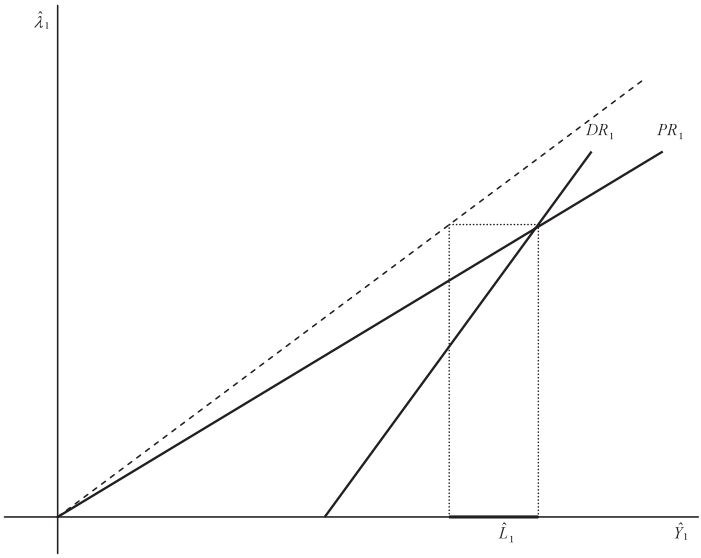

Figure 1 DR and PR functions in the investment goods sector

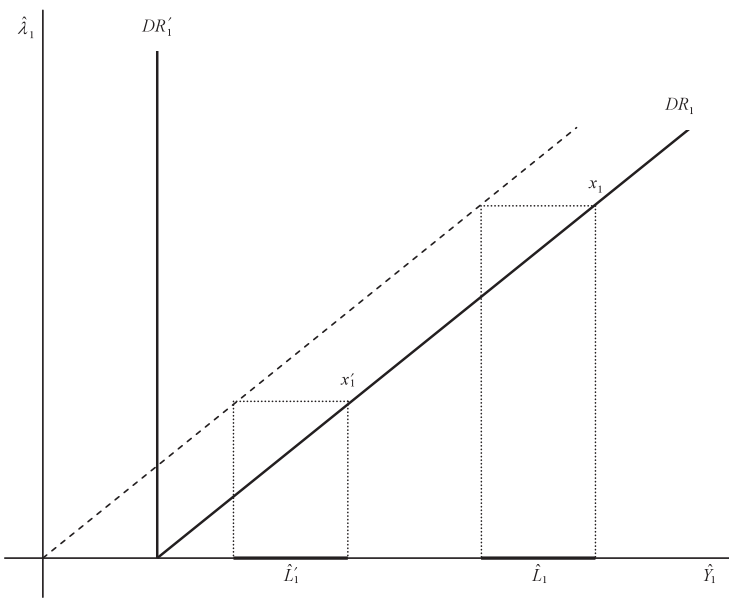

Figure 2 Effect of a change in the slope of the DR function on employment growth

Thereby, we obtain

$$\frac{\partial B_1}{\partial a_1}=\frac{(1-a_2)(1-a_2\phi_2)}{\{1-a_2[a_1(1-\phi_2)+\phi_2]\}^2},$$

where $0<a_2<1$ and $\phi_2<1$ engender $\partial B_1/\partial a_1>0$.

3. 2 Cumulative causation in the consumer goods sector

The PR function in the consumer goods sector is represented by Eq. (2); its slope is positive in the (Y_2, λ_2) plane. The DR function can be derived from Eqs. (1), (15), and (20).

$$\hat{Y}_2=B_2\hat{\lambda}_2+D_{21}+D_{22}+D_{23} \tag{22}$$

$$B_2=\frac{a_2(1-a_1)}{1-a_1[a_2(1-\phi_1)+\phi_1]},\quad D_{21}=\frac{a_2(1-\phi_1)A_1}{1-a_1[a_2(1-\phi_1)+\phi_1]}$$

$$D_{22}=\frac{(1-a_1\phi_1)A_2}{1-a_1[a_2(1-\phi_1)+\phi_1]},\quad D_{23}=-\frac{a_2(1-a_1)\phi_1}{1-a_1[a_2(1-\phi_1)+\phi_1]}$$

We assume $1-a_1[a_2(1-\phi_1)+\phi_1]>0$, as in the case of the investment goods sector.

The slope of the DR function in sector 2, $(1/B_2)$, is expected to be positive on the plausible condition of $a_1<1$ (refer to the estimated result of Table 4), because increased labor productivity growth in sector 2 raises demand growth of consumer goods through a fall in its price. The sufficient condition on the steep slope of the DR function in sector 2 is contrary to that in sector 1. In the previous section, we explained that a small elasticity of the investment with respect to profit causes a small a_1. Furthermore, we obtain

$$\frac{\partial B_2}{\partial a_1}=-\frac{a_2(1-\phi_1)}{\{1-a_1[a_2(1-\phi_1)+\phi_1]\}^2}<0.$$

Therefore, the slope of the DR function in sector 2 becomes moderate if investment is sufficiently independent of profit income.

The intersection of the DR function and Y_2 axis is the sum of D_{21}, D_{22}, and D_{23}. Actually, D_{21} represents the combined effect of the trend term of investment growth, consumption growth, and export growth of investment goods on demand growth in sector 2. Furthermore, D_{22} is the growth rate of savings rate, investment growth, and export growth of consumer goods on demand growth in sector 2. In addition, D_{23} represents the effect of the trend of labor productivity growth of sector 1 on demand growth in sector 2.

Figure 3 depicts the DR function (DR_2) and the PR function (PR_2) in sector 2

for $D_{21}+D_{22}+D_{23}>0$. The difference between demand and productivity growth is the growth rate of employment, which is designated as $\hat{L}_2$.

Finally, the effect of dynamic returns to scale becomes a main cause of disproportionate demand and employment growth in both sectors. The positions of the DR functions in each sector depend largely on the Verdoorn coefficient. For example, consider the case in which the Verdoorn coefficient of sector 1 is unity: $\psi_1=1$. In this case, D_{21} disappears in Eq. (22), which implies that the position of the DR function in sector 2 does not change even if A_1 becomes larger. This pattern of behavior is explainable as follows. When an increase in A_1 raises demand growth in sector 1, $\hat{Y}_1$, this might raise the growth rate of employment in this sector if we assume that ψ_1 is sufficiently small. In turn, employment growth in sector 1 can positively affect demand growth in sector 2 through expansion of consumption demand. However, if ψ_1 equals unity, an increase in $\hat{Y}_1$ raises $\hat{\lambda}_1$ equally. Consequently, the growth rate of employment in sector 1, $\hat{L}_1(\equiv\hat{Y}_1-\hat{\lambda}_1)$, does not change, so a rise in A_1 causes no change in either demand or employment growth in sector 2. Similarly, for the case in which the Verdoorn coefficient of sector 2 is unity, namely $\psi_2=1$, A_2 does not affect the position of the DR function in sector 1.

4. Estimation of the DR function and the PR function

4.1 Classification of an input-output table into two sectors

Because our cumulative causation model has many parameters, we must estimate the parameters using Japanese economic data for 1977–2003 and thereby

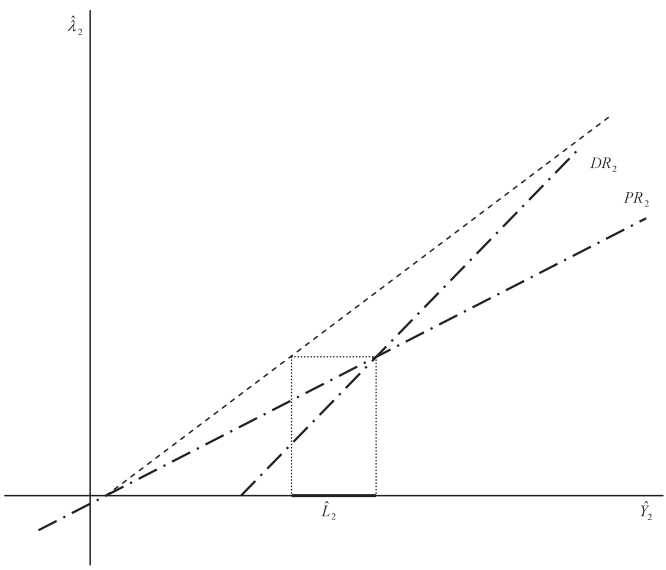

Figure 3 DR and PR functions in the consumer goods sector

derive the DR and PR functions during the 1980s and 1990s. Consequently, we can confirm the interrelation among labor productivity, demand, and employment growth explained in the preceding section.

We can divide all Japanese industries into an investment goods sector and a consumption goods sector in the following manner. This paper identifies "Machinery Manufacturing" ("Machinery," "Electrical Machinery, Equipment, and Supplies," "Transport Equipment," "Precision Instruments") and "Construction" as the investment goods sector in The Linked Input-Output Tables in *1980-1985-1990* and in *1990-1995-2000* (Ministry of Internal Affairs and Communications). Industries that do not correspond to sector 1 are identified as the consumer goods sector. Our classification of the economy into two sectors is apparently valid for Japan because, on the one hand, investment demand for goods produced in "Machinery Manufacturing" and "Construction," which we defined as sector 1, accounted for 84.4% of all investment demand in 1995. On the other hand, consumption demand for goods produced in sector 2 accounted for 95.6% of aggregate consumption demand during that year.

4. 2 Japanese economic performance since the 1980s

Before beginning the estimation, we briefly surveyed the Japanese economy's performance from the 1980s to the early 2000s, because it is useful to confirm the effectiveness of our two-sector model.

Recently, the Japanese economy experienced both a decade of prosperity (in the 1980s) and a stagnation period, the so-called lost decade of the 1990s; the annual growth rate of real GDP was 4.63% during the 1980s and 1.16% during the 1990s. Furthermore, the employment growth rate fell from 0.94% during the former period to −0.01% during the latter; the unemployment rate increased from 2.1% in 1991 to 5.2% in 2003. However, all Japanese industries did not necessarily show similar performance during the same period: the investment goods sector's activity slumped although the consumer goods sector experienced only a slight change in the 1990s. Table 1 presents the growth rate of real GDP in the investment goods sector and in the consumer goods sector during 1977-2003 in Japan. Real GDP growth in sector 1 was high in the 1980s (1977-1991), but it was depressed to a very low level in the 1990s (1991-2003): the average annual growth rate of real GDP decreased from 5.86% in the 1980s to −0.09% in the 1990s. In particular, the growth rate in "Machinery Manufacturing" fell from the former period to the latter by 7.88 points. The growth rate in sector 2 tended to decline beginning in the late 1980s, but it did not decrease considerably during the "lost decade" in contrast with that of the investment goods sector. The consumer goods GDP grew annually by 4.07% during the 1980s and by 1.45% during the 1990s.

This table also shows the two sectors' annual employment growth rates during each period. Employment growth for the investment goods sector and the consumer goods sector were equivalent in the 1980s; the employment growth rate of "Machinery Manufacturing" was 1.23%, and this became the driving force

Table 1 Annual growth rates of real GDP and employment (unit: %)

	Real GDP		Employment	
	1977–1991	1991–2003	1977–1991	1991–2003
Investment goods sector	5. 86	−0. 09	1. 16	−0. 94
Machinery Manufacturing	10. 50	2. 62	1. 23	−2. 03
Construction	3. 52	−2. 61	1. 11	−0. 09
Consumer goods sector	4. 07	1. 45	0. 96	0. 12
Service	5. 04	2. 43	2. 30	1. 28
Other manufacturing industries	2. 65	−1. 05	−0. 49	−2. 06

Note: Machinery Manufacturing includes "Machinery," "Electrical Machinery, Equipment and Supplies," "Transport Equipment," and "Precision Instruments." Service comprises "Electricity, Gas and Water Supply," "Wholesale and Retail Trade," "Finance and Insurance," "Real Estate," "Transport and Communications," and "Service activities." "Other manufacturing industries" is defined as the manufacturing industries except for Machinery Manufacturing. Real GDP in Machinery Manufacturing, Service and Other manufacturing industries are calculated as the weighted average of those of corresponding industries. This table is abstracted from real GDP and employment growth of "Agriculture, Forestry, and Fishing," "Mining," "Producers of government services public service," and "Producers of private non-profit services to households." All data are obtained from the *Annual Report on National Accounts* (Cabinet Office, Japan).

behind the rapid growth of employment in sector 1. In the 1990s, however, the growth rate of employment in "Machinery Manufacturing" decreased to −2.03%. This was the main factor leading to a drastic fall in the employment growth of sector 1, and also the increased unemployment rate. Nevertheless, it is worth mentioning that the employment growth rate in the consumer goods sector was positive: in particular, employment in the service industries grew annually by 1.28%. During this period, this sector acted as an employment buffer for the overall economy.

4. 3 Estimated results

In the following, we provide the estimated results of the PR functions and investment functions in both sectors. Table 2 presents the estimated PR function represented by Eqs. (1) and (2). Regarding the PR function in the investment goods sector, the pooled data in "Machinery," "Electrical Machinery, Equipment, and Supplies," and "Transport Equipment" were used. We estimated the PR function in the consumer goods sector for "Service" and for "Other Manufacturing Industries" separately, because the production technologies of those two industries were considered to be much different. We used pooled data in "Wholesale and Retail Trade," "Finance and Insurance," "Transport and Communications," and "Service Activities" for estimation of the PR function in "Service" and those in "Food Products and Beverages," "Textiles," and "Others" for estimation of the PR function in "Other Manufacturing Industries."

A characteristic that was common to all estimated results was a high Verdoorn coefficient[7]. Although it is curious that the Verdoorn coefficient of "Service" was higher than that of sector 1, the result was attributable to institutional factors rather than technological factors. In Japan, employment has been secure in every industry for a long time, as the term "lifetime employment"[8] indicates. Such an employment system is well known to have both advantages and disadvantages: the system enables workers to acquire firm-specific skills, but labor hoarding takes place in firms during recessions (in other words, lifetime employment implies low employment flexibility).

Different from institutional factors, technological factors were considered to affect the trend term of labor productivity growth, ϕ_1 and ϕ_2. Those parameters were higher in the manufacturing sector than in "Service"; specifically, the value of ϕ_2 for "Service" was negative in both periods. Moreover, those parameters,

Table 2 Estimation results for the PR function

	Investment goods sector			Consumer goods sector			
				Service		Other manufacturing industries	
	1977–1991	1991–2003		1977–1991	1991–2003	1977–1991	1991–2003
ϕ_1	0. 004 (0. 584)	0. 016 (3. 147)	ϕ_2	− 0. 016 (− 3. 966)	− 0. 006 (− 1. 762)	− 0. 002 (− 0. 395)	0. 029 (5. 350)
ϕ_1	0. 785 (15. 608)	0. 921 (16. 670)	ϕ_2	0. 967 (17. 347)	0. 976 (10. 334)	1. 016 (13. 938)	0. 707 (7. 231)
n	45	39	n	60	52	45	39
Adj. R^2	0. 846	0. 879	Adj. R^2	0. 836	0. 675	0. 815	0. 574

Note: Ordinary least squares (OLS) method was used. Variables in parentheses are *t*-values, *n* signifies the number of observations, Adj. R^2 is the adjusted coefficient of determination. We used real GDP divided by the number of employees to represent labor productivity, instead of a reciprocal of the vertically integrated labor coefficient because it is difficult to obtain the annual data of vertically integrated labor coefficient. It is noteworthy that the vertically integrated labor coefficient, $\mathbf{L}(\mathbf{I}-\mathbf{A})^{-1}$, is equal to $\mathbf{LI}+\mathbf{LA}+\mathbf{LAA}+\Lambda+\mathbf{L}\,\mathbf{A}\underset{\infty}{\underbrace{\Lambda}}\mathbf{A}$ and that its first term, **LI**, is the most influential factor determining the level of that coefficient. Therefore, the amount of direct and indirect labor is considered to be approximate to the amount of direct labor. All data are obtained from the *Annual Report on National Accounts*.

[7] Regarding estimation of the Verdoorn coefficient using time-series analysis, Stoneman (1979) estimates the coefficient of the United Kingdom as 0.665 during 1800–1969. Naastepad (2006) estimates the coefficient as 0.630 for the Netherlands during 1960–2000. Uni (2007) estimates the coefficient of the U. S. manufacturing industry as 0.444 during 1978–1987 and 0.753 during 1988–2001. See also McCombie and Roberts (2009) for the survey of the Verdoorn law using cross-regional or cross-industry data.

[8] "Lifetime employment" refers to the traditional Japanese employment system. In this system, people continue working in one firm from the time they leave college until the time they retire. Yamada (2000) says, "Since some dismissals and so-called involuntary early retirement do occur, it would be more precise to state that there is no absolute guarantee of job security, but rather an unspoken commitment by management to exert itself to avoid dismissals" (p. 22).

including those of "Service," increased from the 1980s to the 1990s, most likely due to the development of information and communication technology.

We presume here the overall PR function of sector 2 as the weighted average of the PR functions of "Service" and that of "Other Manufacturing Industries" for the sake of convenience. The PR function of sector 2 was $\hat{\lambda}_2 = -0.014 + 0.973\hat{Y}_2$ in the 1980s and $\hat{\lambda}_2 = -0.004 + 0.955\hat{Y}_2$ in the 1990s.

Table 3 presents the estimated results of the investment function in both sectors represented by Eqs. (13) and (14)[9]. A remarkable change in the trend of the growth rate of investment, α_1 and α_2, occurred between the 1980s and the1990s. In both sectors, these terms were close to zero in the 1990s, although they were considerably higher in the 1980s. Firms' disincentives to invest in the 1990s resulted from the over-accumulation of capital in the late 1980s during the so-called bubble economy: the average annual growth rate of production capacity index of the manufacturing sector was 1.79% between 1985 and 1992, then fell

Table 3 Estimation results for the investment function

Investment goods sector			Consumer goods sector		
	1977Q1 −1991Q1	1991Q1 −2004Q1		1977Q1 −1991Q1	1991Q1 −2004Q1
α_1	0. 048 (4. 016)	−0. 001 (−0. 074)	α_2	0. 042 (3. 670)	0. 004 (0. 620)
β_1	0. 415 (4. 728)	0. 267 (5. 585)	β_2	0. 414 (3. 522)	0. 412 (5. 293)
n	56	52	n	56	52
Adj. R^2	0. 280	0. 372	Adj. R^2	0. 172	0. 346
D.W.	1. 826	1. 793	D.W.	1. 875	2. 042

Note: OLS is used with AR (1). D. W. are Durbin−Watson statistics, for which transformed values are indicated. Nominal investment of sector 1 is defined as the sum of the increase in "Other tangible fixed assets," the increase in "Construction in process," and "Depreciation expenses" of "Machinery," "Electrical Machinery, Equipment and Supplies," and "Transport Equipment." These quarterly data were obtained from *Financial Statements Statistics of Corporations by Industry*. The real investment of sector 1 is defined as the nominal investment divided by the gross fixed capital formation deflator. The real profit of sector 1 is the sum of "Operating profits" and "Depreciation expenses" of those three industries, divided by the gross fixed capital formation deflator. The real investment and profit of sector 2 are calculated using the same method with quarterly data of "Wholesale and Retail Trade," "Transport and Communications," "Service Activities," "Food Products and Beverages," "Textiles," and "Others." We use the two-quarter-lagged growth rate of real profit to estimate the investment function of sector 1.

[9] Because investment growth was largely affected by the short-term cyclical behavior of the wage share in Japan, we were unable to estimate the long-term parameters of Eqs. (13) and (14) directly. Therefore, we obtained β_i by substituting $\hat{\pi}_i = 0$ into estimated results of Eqs. (8) and (10).

annually by −0.79% from 1992 to 2003 (*Indices of Industrial Production*, Ministry of Economy, Trade and Industry, Japan). Therefore, large stocks of idle equipment in the manufacturing sector existed since the late 1980s, which in turn led to the stagnation of investment demand in the 1990s.

Table 4 presents other parameters. Comparing parameters in the 1990s with those in the 1980s, the growth rate of the sum of the export of and consumption demand for investment goods $\hat{e}'_1$ decreased considerably. This was caused not by a decrease in the consumption demand, but rather by a decrease in the export demand. Moreover, this table portrays the fact that the savings rate decreased more rapidly during the 1990s than in the 1980s. A decreasing savings rate during a recession is often observed in many developed countries, because "consumers attempted to maintain spending in the face of falling incomes" (Glyn, 2006, p. 53).

We additionally present parameters a_1, a_2, A_1, and A_2 in Table 4. Two points are noteworthy with regard to these parameters: a_1 was relatively small during two periods, and A_2 increased from the 1980s to the 1990s. The small value of a_1 resulted from the small elasticity of investment with respect to profit (see Table 3); an increase in A_2 was attributed to the above-described decreasing growth of the savings rate.

Table 4 Other parameters

	1980s	1990s		1980s	1990s
Δ_1	0. 136	0. 132	σ	0. 310	0. 298
Δ_2	0. 316	0. 596	$\hat{s}$	−0. 035	−0. 061
Δ_3	0. 394	0. 272	a_1	0. 240	0. 275
$\hat{e}'_1$	0. 064	0. 027	a_2	0. 828	0. 782
$\hat{e}'_2$	0. 003	0. 012	A_1	0. 053	0. 008
θ	0. 883	0. 897	A_2	0. 016	0. 019

Note: Using an input-output table, we calculate the share of investment demand, which is equal to the sum of Δ_1 and Δ_2, and the share of the sum of the consumption and export, Δ_3, in all demand in sector 1. Next, we calculate the ratio of investment of sector 1 to investment of sector 2 using data of "Investment in plant and equipment excluding software" in *Financial Statements Statistics of Corporations by Industry*. Subsequently, we multiply this ratio by the share of investment in all demand in the investment goods sector and define it as Δ_1; s is defined as "savings" divided by "National disposable income" in the *Annual Report on National accounts*. Furthermore, $\hat{e}'_1$, $\hat{e}'_2$, θ, and σ are calculated using data of the input-output table, the gross fixed capital formation deflator, and the CPI.

5. Japanese growth regimes

5.1 1980s

This section provides the DR and PR functions in both sectors by substituting parameters into our model. The DR function in the investment goods sector in the 1980s is represented by Eq. (23); the PR function in this sector is expressed as Eq. (24)[10].

$$\hat{Y}_1 = 0.229\hat{\lambda}_1 + 0.057 \tag{23}$$
$$\hat{\lambda}_1 = 0.000 + 0.785\hat{Y}_1 \tag{24}$$

The DR function in the consumer goods sector in the 1980s is expressed as Eq. (25); the PR function in this sector is expressed as Eq. (26).

$$\hat{Y}_2 = 0.686\hat{\lambda}_2 + 0.027 \tag{25}$$
$$\hat{\lambda}_2 = -0.014 + 0.973\hat{Y}_2 \tag{26}$$

These functions are depicted in Fig. 4. Characteristics of the DR function in sector 1 in the 1980s are that its slope is steep and an intersection of the function and $\hat{Y}$ axis is placed rightward. A main cause of the former is the small value of a_1, resulting from the small elasticity of investment with respect to profit in both sectors. The cause of the latter is a large A_1, which resulted from the strong trend of the growth rate of investment and large export growth of investment goods.

Regarding sector 2, the DR function in the 1980s has a moderate slope; an intersection of the function and the $\hat{Y}$ axis is placed leftward. The leftward position of the intersection results from the large effect of dynamic increasing returns to scale in sector 1, as explained in 3.2. Table 5 presents components of the constant term in the DR function. Because of the rapid growth of investment and export for investment goods, $D_{11}(=0.053)$ is the most important factor that determines the position of the DR function in sector 1. Nevertheless, such a good performance of sector 1 does not spread to the position of the DR function in sector 2, $D_{21}=0.010$, because of the high Verdoorn effect in sector 1. Similarly, large A_2 with the decreasing savings rate only slightly affects the position of the DR function in sector 1, $D_{12}=0.000$, although it shifts the position of the DR function in sector 2 rightward, $D_{22}=0.016$.

In the 1980s, in our model, the growth rate of demand in sector 1 is 6.95%, which is larger than the growth rate of demand (5.24%) in sector 2[11]. Furthermore, the growth rate of employment in sector 1 is 1.49%, which is almost identical to the growth rate of employment (1.54%) in sector 2.

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[10] Statistically non-significant parameters are assumed to be zero.

[11] It is necessary to mention here that these values are slightly larger than the real GDP data described in Table 1 because our model abstracts from imports.

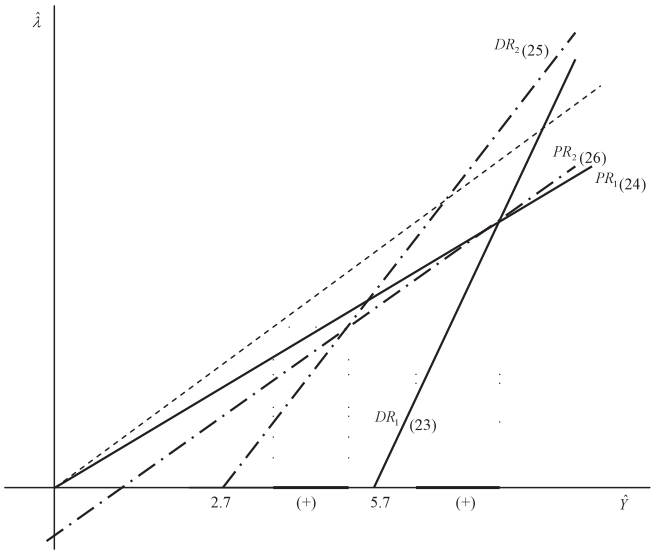

Figure 4 DR and PR functions in the 1980s

Table 5 Components of the constant term in the DR function

Investment goods sector			Consumer goods sector		
	1980s	1990s		1980s	1990s
D_{11}	0. 053	0. 008	D_{21}	0. 010	0. 001
D_{12}	0. 000	0. 001	D_{22}	0. 016	0. 019
D_{13}	0. 003	0. 001	D_{23}	0. 000	− 0. 011
Sum	0. 057	0. 010	Sum	0. 027	0. 008

Note: D_{i1} denotes the combined effect of the trend term of investment and consumption plus export growth for investment goods on the constant term of the DR function in the i th sector. D_{i2} is the combined effect of the growth rate of the savings rate and investment growth plus export growth for consumer goods on its constant term in the i th sector. D_{i3} represents the effect of the trend of labor productivity growth of one sector on its constant term in another (i th) sector.

5. 2 1990s

The DR function in the investment goods sector in the 1990s is expressed as Eq. (27); the PR function in this sector is expressed as Eq. (28).

$$\hat{Y}_1 = 0.253\hat{\lambda}_1 + 0.010 \tag{27}$$
$$\hat{\lambda}_1 = 0.016 + 0.921\hat{Y}_1 \tag{28}$$

The DR function in the consumer goods sector in the 1990s is expressed as Eq. (29); the PR function in this sector is expressed as Eq. (30).

$$\hat{Y}_2 = 0.720\hat{\lambda}_2 + 0.008 \tag{29}$$
$$\hat{\lambda}_2 = -0.004 + 0.955\hat{Y}_2 \tag{30}$$

Those functions are presented in Fig. 5. The PR function in sector 1 shifts upward in the 1990s with the strong trend of labor productivity growth, $\phi_1 = 0.016$. Regarding the DR function in sector 1, its slope changes only slightly from the 1980s to the 1990s. However, an intersection of the DR function and $\hat{Y}$ axis decreases considerably from the previous one because of the sharp decline of A_1 with the weak trend of the growth rate of investment and the low export growth for investment goods. In sector 1, the positive effect of an upward shift of the PR function on its demand growth is eliminated by a moderate slope of the DR function and its leftward shift. Consequently, in our model, shifts of these types merely cause a decrease in employment growth in sector 1. Our model shows that the growth rate of demand in sector 1 decreases to 1.80%, and its growth rate of employment decreases to -1.46%, each of which is much smaller than those in the 1980s.

Regarding the DR function in sector 2, an intersection of the DR function and $\hat{Y}$ axis decreases. This decrease, however, is not caused by the same factors that make DR function of sector 1 shift leftward. A reason for the decreased intersection is the above-described strong trend of labor productivity growth of sector 1, which is represented by $D_{23} = -0.011$ in Table 5. But, it is necessary to point out that a negative value of D_{23} is cancelled out by the decreased savings rate: if, on the contrary, the savings rate is constant − that is, $\hat{s} = 0$ − then the sum of D_{21}, D_{21}, and D_{23} becomes negative (as do the growth rate of demand and labor productivity). The decreasing savings rate is one reason that output and employment growth of sector 2 remain unchanged.

In addition to the decreasing savings rate, the moderate slope of the DR function of sector 2 plays an important role in a smaller decrease in output and employment growth in this sector. Because increased labor productivity growth in sector 2 raises the demand growth of this sector *sufficiently*, through a fall in the price of consumer goods in the case in which the slope of DR function is moderate, its demand and employment growth do not decrease much. Our model indicates

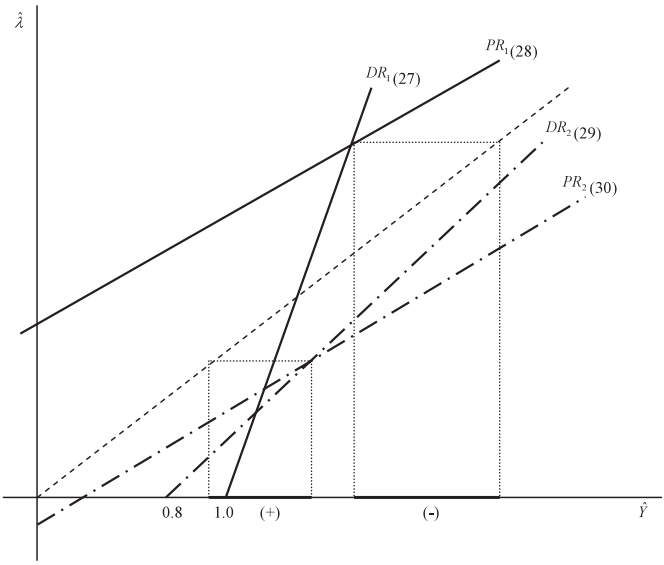

Figure 5 DR and PR functions in the 1990s

the growth rate of demand in sector 2 as 1.65% in the 1990s and the growth rate of employment as 0.47%, which resemble the actual data presented in Table 1.

6. Concluding remarks

The interrelation among output, labor productivity, and employment growth from the viewpoint of Nicholas Kaldor's cumulative causation has been analyzed in many studies, by making use of macroeconomic model. In these previous models, it is mainly through the wage share that labor productivity growth affects other variables. This analytical device engenders the result that the upward shift of the PR function with technological progress or organization reform can have no impact on the output growth when the wage share is maintained as constant (in other words, the slope of the DR function becomes vertical). In contrast, this paper presents a two-sector (investment goods and consumption goods sectors) model instead of a macroeconomic framework. We showed that the upward shift of the PR function in one sector has a positive impact on its demand growth through a change of relative price, because the DR function has a positive slope in both sectors, although it has a negative impact on employment growth. This result implies that improving the supply side condition increases demand growth when the wage shares in both sectors remain constant.

We apply our model to Japan from the 1980s to the beginning of the 2000s to confirm the validity of our result. Our empirical analyses reveal that rapid labor productivity growth, especially that in the investment goods sector during the

1990s, was sufficient to raise its demand growth because the positive slope of the DR function was maintained. However, the slow growth of investment, the sharp decline of exports of investment goods, and the small elasticity of investment with respect to profit eliminated the possibility that the upward shift of PR function in the investment goods sector was able to raise its demand growth. This shift of PR function, on the other hand, exerted a larger negative influence not only on employment growth in the investment goods sector, but also on both demand and employment growth in the consumer goods sector, thereby creating the high rate of unemployment that prevailed in Japan during the 1990s.

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