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A Classical-Marxian Growth Model of Catching Up and the Cases of China, Japan, and India: 1980–2014

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Abstract

This article presents a classical-Marxian model of catching up wherein the leader country employs a technique with higher labor productivity and lower capital productivity than the follower's technique. The follower's higher profit rate allows for faster capital accumulation than the leader's. During the catching up phase, labor productivity rises while capital productivity and profit rate decline in the follower country. In addition, we discuss some stylized facts of catching up in China, Japan, and India in relation to the United States between 1980 and 2014. Catching up occurred when capital accumulation was higher in the followers. However, a high capital accumulation in the follower country can reduce capital productivity and profit rate to a level lower than the leader's, putting the process at risk.
JEL Classification: O33, O41, O47

Keywords

catching up, technical change, profit rate, labor productivity, mechanization

1. Introduction

Unequal development is one of the main features of capitalism. Countries have exhibited differences in their productivity and growth performances throughout history (Kaldor 1970; Pritchett 1997). Although some nations can catch up to the labor productivity and well-being of developed economies, others fall behind. One of the questions faced by the growth theory is how to

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explain the processes of catching up and falling behind between nations.[1] As Abramovitz (1986) and Linden (2007) pointed out, some of these mechanisms result in unequal development.

This article proposes a growth model in the classical-Marxian tradition in which capital accumulation and its determinants play a central role in the processes of catching up and falling behind. Accumulation accounts for the differences in economic growth between the leader and the follower countries. Distinct approaches highlight capital accumulation as central to boosting growth. This accumulation also functions as a measure of a country's effort to catch up while encompassing other relevant factors for economic growth—for example, the institutional organization of society.

The model extends the catching-up hypothesis of technological diffusion in labor productivity discussed by Foley and Michl (1999) to both labor and capital productivities. There are three important features in the model. First, the leader country's initial technique has higher labor productivity and lower capital productivity than the follower countries, which implies that the capital/labor ratio of the leader country is higher than the follower country and that, at low levels of real wages, the wage-profit frontier of the follower country dominates the wage-profit frontier of the leader. In the present model, it represents one of the advantages of backwardness (Gerschenkron 1962). It contrasts with Duménil and Lévy (2010), who proposed that both productivities are higher in the leader country.

The catching-up path corresponds to rising labor productivity and capital/labor ratio and declining capital productivity. The technical change in the follower country takes a Marx-biased form (Foley and Michl 1999). Mechanization is the typical pattern of technical change, particularly during industrialization.[2] Szirmai (2012) suggested that industrialization played an important role in the process of catching up for late-industrialized countries. Deindustrialization and falling behind in many Latin American countries after 1980 were accompanied by declining labor productivity and rising capital productivity (Marquetti and Porsse 2017). Villanueva and Jiang (2018) called this process reversed Marx-biased technical change and associated it with deindustrialization, the middle-income trap, and the poverty trap. Technical change in the United States also followed the Marx-biased pattern in the long term, though punctuated by periods in which labor and capital productivities increased (Marquetti 2003).

Second, a necessary condition for catching up is that capital accumulation in the follower is higher than in the leader. Accumulation of capital is fundamental to the diffusion of technical progress that is embodied in new capital goods. The capital accumulation in the Cambridge equation is a function of the profit rate and the saving rate. From the perspective of economic development theory, a big push is necessary for the process of catching up.

Third, the processes of catching up or falling behind occur in labor and capital productivities with consequences for the paths of the profit rate and capital accumulation. The possibility of different velocities of catching up in labor and capital productivities exists. In the neoclassical tradition, McQuinn and Whelan (2007) estimated that capital productivity converged to its

[1]In the Solow (1956) growth model, convergence refers to the approximation of a country to its steady state. The hypothesis of absolute convergence refers to the convergence to the same steady state if all countries have access to the same technology, equal saving rates, and equal population growth rates. The hypothesis of conditional convergence raises the possibility of distinct steady states among countries due to differences in the saving rates and population growth rates.

[2]Foley, Michl, and Tavani (2018: 40) argued that ''convergence in labor productivity levels has been associated with convergence in the capital/labor ratio, or capital intensity. Both variables have converged 'from below.' By contrast, capital productivity seems to converge on the world leader 'from above.' Nations at low levels of labor productivity have high levels of capital productivity, which then falls in the course of economic development.''

steady state value at the speed of 7 percent per year, while labor productivity converged at 2 percent per year. Our results show that capital productivity catches up faster than labor productivity. It has fundamental consequences for the process of catching up. The decline of capital productivity in the case of a stable wage share reduces the profit rate and capital accumulation in the follower country to a similar or lower level than the leader country before the catching-up phase in labor productivity. It eliminates one of the key advantages of backwardness, the higher profit rate at low real wage.

The model summarizes Marx's (1981) conception of catching up presented in *Capital*, volume 3, chapter 13, the famous chapter on the law of tendential fall in the profit rate. In Marx's words:

> We have seen that at one stage of capitalist development, when the organic composition of capital c : v is 50 : 100 for example, a rate of surplus-value of 100% is expressed in a rate of profit of 66⅔ per cent, while at a higher stage of development, where c : v is 400 : 100 say, the same rate of surplus-value is expressed in a rate of profit of only 20 per cent. What applies to different successive stages of development in one country applies also to different countries that find themselves in differing stages of development at the same point in time. In the undeveloped country, where the composition of capital is on the average as first mentioned, the general rate of profit would be 66⅔ per cent, while in a country at much higher level of development it would be 20 per cent. (Marx 1981: 320)

The model is contrasted with some stylized facts of the experiences of catching up and falling behind of the Chinese, Japanese, and Indian economies in comparison with the United States between 1980 and 2014. Japan was very successful catching up until the early 1990s. China has been catching up very rapidly since 1980, while in India the process accelerated in the early 2000s. Catching up occurred when capital accumulation was higher in the follower countries. However, a high capital accumulation in the follower country can reduce the capital productivity and the profit rate to a level similar to or lower than that in the leading country. The fall of the profit rate may reduce capital accumulation in the follower country, which may jeopardize catching up in labor productivity.

The article is organized as follows. In section 2, we present a system to measure the national accounts and technical change. Section 3 displays a basic growth model in the classical-Marxian tradition. In section 4, we extend the model to allow for catching up and falling behind and discuss the central hypotheses of the model. Section 5 discusses the pattern of technical change and the experiences of catching up and falling behind of China, Japan, and India in the period 1980–2014. In section 6, we investigate the relationship between profit rate and catching up and falling behind in these countries. We investigate the relationship between investment rate, capital accumulation, and the process of catching up and falling behind in section 7. Section 8 concludes the article. The description of the data set and further details on the mathematical model are in the appendices.

2. A System to Represent the National Accounts and Technical Change

A growth-distribution schedule allows one to visualize national income accounts. It is based on a generalization of Sraffa's (1960) wage-profit frontier, which was initially employed by Foley and Michl (1999).

For a given country and year, X is the GDP measured at 2011 purchasing power parity (PPPs), the aggregate capital K, which is expressed in the same units of the GDP; the labor input N is the number of employed workers; the total worker's compensation is W; the non-wage income $Z = X - W$, which we refer to as cash flow and includes profits and depreciation allowances, D; the net

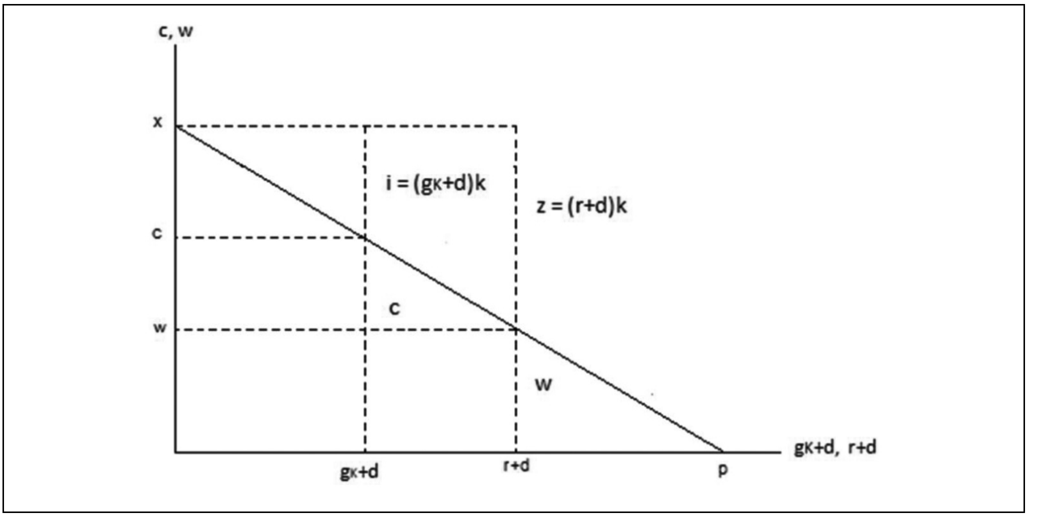

Figure 1. The growth-distribution schedule representing the national account identities. From the expenditure side, it shows the allocation between investment and consumption, $x = c + i = c + (g_K + d)k$. From the income side, it shows the distribution between profits and wages, $x = w + z = w + vk = w + (r + d)k$.

output $Y = X - D$; the net profit $R = Z - D$; the gross investment is I; and social consumption $C = X - I$.

In order to compare countries, it is convenient to express the variables in terms of employed workers. Therefore, x is output per worker, or labor productivity; k is capital per worker, or capital intensity; w is the average real wage; z = cash flow per worker; c = the social consumption per worker (including non-worker consumption); and i is investment per worker. Some variables are normalized by the capital stock: $p = X / K = x / k$ is output per unit of capital, or capital productivity; $v = Z / K$ is the gross profit rate; $d = D / K$ is the depreciation rate; $r = v - d$ is the net profit rate; $g_K + d = I / K$ is the capital accumulation, which is the ratio of gross investment to the capital stock. The growth rate of the variables, for example x, is computed as $g_x = \Delta x / x$, so that g_x represents the labor productivity growth rate, and g_p represents the capital productivity growth rate.

The profit share is $\pi = z / x$, and the wage share is $1 - \pi$. The profit rate $v = \pi p$ can be calculated as the multiplication between profit share (a distribution variable) and capital productivity (a technological variable).

The growth-distribution schedule, shown in figure 1, illustrates the interdependence among these variables in the (x, p) space. It is a straight line with a vertical intercept equal to labor productivity x and a horizontal intercept equal to capital productivity, p. The capital/labor ratio is the negative slope of this line.

Looking at the national accounts from the expenditure side, $x = c + i = c + (gK + d)k$, labor productivity is divided into the gross investment per worker, i, and the social consumption per worker, c, at the capital accumulation, $gK + d$. The maximum capital accumulation is equal to p when $c = 0$. The maximum consumption per worker corresponds to $g_K + d = 0$, thus being equal to labor productivity, x. Similarly, but from the income side of the national accounts, $x = w + z = w + (r + d)k$, labor productivity is divided into the real wage per worker (w) and cash flow per worker ($z = Z/N$) at the gross profit rate, $r + d$. The maximum profit rate corresponds to $w = 0$, thus being equal to capital productivity, p. The maximum real wage occurs when $r + d = 0$, being equal to labor productivity, x.

A growth-distribution schedule captures technical change at the macroeconomic level. Increases in labor productivity raise the vertical intercept, and declines in capital productivity move the horizontal intercept to the left. Harrod-neutral or pure labor-saving technical progress rotates the growth-distribution schedule clockwise around its horizontal intercept. Solow-neutral or pure capital-saving technical change rotates the growth-distribution schedule counterclockwise around its vertical intercept. Hicks-neutral or input-saving technical change shifts the growth-distribution schedule outward, parallel to itself, leaving capital intensity unchanged. The Marx-biased technical change corresponds to a rise of the vertical intercept (labor productivity) and a decline of the horizontal intercept (capital productivity).

3. A Simple Growth Model

Both Marglin (1986) and Foley and Michl (1999), among others, developed straightforward growth models in the classical-Marxian tradition. Each one throws light on the basic causal relationship between the variables and describes the schematic behavior of a closed economy without government. The Leontief production function, with constant returns to scale, depicts the technology; the economy produces one commodity, X, that is consumed and invested. The fixed capital stock, K, and labor, N, are the inputs. The production function is represented by:

$$X = min(pK, xN). \tag{1}$$

The income is distributed between capitalists and workers. Capitalists receive profits and workers receive wages. The wage-profit frontier illustrates the trade-off between profits and wages:

$$w = x - (r + d)k. \tag{2}$$

Output can be invested or consumed. The trade-off between capital accumulation and consumption is indicated by the consumption-growth rate frontier:

$$c = x - (g_K + d)k. \tag{3}$$

The distribution and growth spheres are linked by some hypotheses about saving and investment decisions. For simplicity, it is assumed that workers consume their entire income and capitalists save a proportion s of their profits, $1 \geq s > 0$. The saving function can be written as:

$$S = sZ = s(R + D), \tag{4}$$

in which S = total savings. Employing the assumption that investment is equal to saving, we obtain:

$$I = sZ = s(R + D). \tag{5}$$

Dividing both sides by capital stock, the Cambridge equation emerges:

$$gK + d = s(r + d) = sv. \tag{6}$$

Equations 2, 3, and 6 provide the basic framework for different economic approaches. In the classical-Marxian tradition, the distribution is exogenously determined, and labor supply is elastic at the subsistence wage. Ricardo (1911) explained this shape using the Malthusian population theory, while Marx (1981) considered the existence of a reserve army of workers. According to

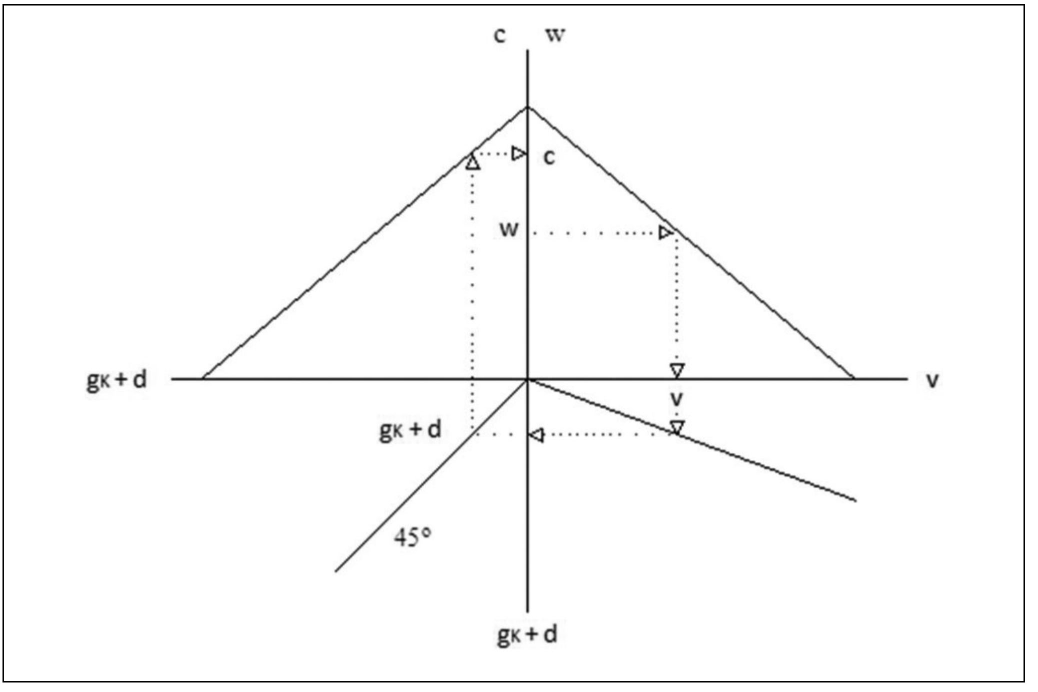

Figure 2. The representation of the classical-Marxian growth model. The endogenous variables are determined in a sequence. First, the real wage, *w*, is computed and then the profit rate, *v*; the next step is the determination of capital accumulation, $g_K + d$. Finally, the social consumption per worker, *c*, is calculated.

Marx, the real wage depends on institutional and historical factors, with labor supply adjusting to capital accumulation.

Following this tradition, and in line with the historical experience, we employ the assumption of constant wage share. Real wage is determined by:

$$w = (1 - \pi)x. \tag{7}$$

Thus, in the classical-Marxian tradition, the growth is endogenously determined. The endogenous variables in the model are calculated in sequential steps. First, the real wage is determined by Equation 7, then the profit rate is calculated by Equation 2; the real wage-profit rate schedule is shown in figure 2. The next step is the computation of capital accumulation by the Cambridge equation, which is depicted in the fourth quadrant in figure 2. Finally, the social consumption per worker is calculated by the consumption-growth rate schedule, as seen in the third quadrant of figure 2. Income distribution and technology determine the profit rate. The profit rate and the saving rate determine the capital accumulation.

4. A Model of Catching Up and the World Patterns of Technical Change

In order to explore the complex dynamics of catching up and falling behind, we present a model in the classical-Marxian tradition. Next, we depict some stylized facts that support the key assumptions of our theoretical model.

4.1. The model

Countries' dynamics of catching up and falling behind can be understood through the classical-Marxian model. New techniques are not a public good and therefore have a diffusion cost, and workers in the follower country need time to learn how to use them. Moreover, the employment of new techniques by a follower country requires access to machines and equipment, education of the labor force, and a learning period for both firms and workers. Consequently, it is easier and quicker to adapt the techniques developed in the leader country than to discover new ones.

The follower countries have a technical gap in relation to the leader. This gap implies lower labor productivity ($x^F < x^L$) and higher capital productivity ($p^F > p^L$) for the follower in comparison with the leader. Gerschenkron (1962) pointed out that the greater the gap, the larger the growth possibilities of the follower countries.[3] A high capital accumulation is a necessary condition to benefit from backwardness, which is a necessary condition for catching up.[4]

Although our model is similar to Foley and Michl's (1999), the equations used herein for the growth rates of labor productivity and capital productivity are assumptions we made based on empirical observation. There are two main differences. First, we consider labor and capital productivities, while Foley and Michl displayed just the equation for labor productivity. They did not present an equation for catching up in capital productivity, despite raising this possibility. Second, in our model, catching up takes place only if capital accumulation in the follower is greater than in the leader country. It is a measure of the ''effort a country makes to catch up through spending on education or investment in new capital goods that embody the latest technology'' (Foley and Michl 1999: 133). Again, Foley and Michl discussed this possibility without presenting a formal equation.

The growth rate of labor productivity in the follower depends on the labor productivity growth in the leader country ($g_x{}^L$), the technical gap in labor productivity ($a = (x^L - x^F)/x^L = 1 - x^F/x^L$), and the term of catching up (ψ). This term is either positive when capital accumulation is higher in the follower than in the leader, or equal to zero, or negative in the opposite case. Thus, the growth rate of labor productivity in the follower country is expressed by:

$$g_x{}^F = g_x{}^L + \psi a, \tag{8}$$

where: $\psi = f(g_K^F) > 0$ if $g_K^F > g_K^L$, and $\psi = f(g_K^F) \leq 0$ if $g_K^F \leq g_K^L$.

In the catching-up process, there is an approximation of the growth rates of labor productivity.

Analogously, the growth rate of capital productivity in the follower country hinges on the growth rate of capital productivity in the leader ($g_x{}^L$), the technical gap in capital productivity

[3]Trotsky (1932), in his analysis of the Russian revolution, was one of the first authors to call attention to the privilege of historical backwardness. Maddison (1995a, 1995b) showed that France, Germany, the Netherlands, the United Kingdom, and Japan had higher capital productivity and lower labor productivity than the United States in 1950.

[4]We abstract from questions of current account unbalance, considering that the figure for external savings is equal to zero. The balance of payment constraint (McCombie and Thirlwall 1994) indeed restricts the possibilities to foster growth in developing and developed economies. Although important, the cases of the United States, China, and Japan are exceptions. The United States presented growth rates superior to the predictions by the balance of payments constraint theory. The remaining two countries have grown with a current account surplus, buying US securities and arguably exhibiting growth rates smaller than the balance of payments theory predicts (Lavoie 2006). Ribeiro, McCombie, and Lima (2016) presented a balance of payments-constrained growth model relating technical change and income distribution between wages and profits.

($b = (p^L - p^F)/p^L = 1 - p^F/p^L$), and the term of catching up (θ). It is negative when the capital accumulation in the follower country is greater than in the leader, equal to zero, or otherwise positive. In the follower country, the capital productivity growth rate can be written as:

$$g_p{}^F = g_p{}^L + \theta b, \tag{9}$$

where: $\theta = f(g_K^F) > 0$ if $g_K^F > g_K^L$, and $\theta = f(g_K^S) \leq 0$ if $g_K^F \leq g_K^L$.

In the catching-up process, the capital productivity growth rate in the follower approaches the capital productivity of the leader. Appendix 2 shows that under the assumptions of Equations 8 and 9, the follower country will catch up with the leader.

For simplicity, the growth rates of labor and capital productivities for the leader are considered to be exogenous. Foley and Michl (1999) developed a model with exogenous technical change with a positive growth rate of labor productivity and a negative growth rate of capital productivity. They called this pattern of technical change Marx-biased. These growth rates can be endogenized, as proposed by Kennedy (1964) and Duménil and Lévy (1995). Tavani and Zamparelli (2017) surveyed the literature about the endogenous growth rate of labor productivity.

For the sake of simplicity, two additional hypotheses are the equal capitalist saving rates in the follower and in the leader countries ($s^L = s^F = s$) and the equal profit share in these economies ($\pi^L = \pi^F = \pi$). The saving rates vary between countries and across time. In the period of study, the saving rate was higher in Asian countries than in the United States. However, the opposite occurred in countries located in Latin America and Africa (Loayza, Schmidt-Hebbel, and Servén 2000). Economic growth boosts the saving rate.

The empirical literature shows the importance of considering the self-employed to correctly measure the wage share in developing countries. Treeck (2017) documented a worldwide decline in wage share after 1980 and pinpointed that the labor shares in developing countries remained around 15 percent lower than in advanced countries even after accounting for self-employment. Marx (1981) considered the possibility of different rates of surplus value in developed and less developed countries.

Economic growth in the leader is represented by:

$$x^L = x_0{}^L (1 + g\, x^L)^t$$

$$p^L = p_0{}^L (1 + g_p{}^L)^t$$

$$w^L = (1 - \pi) x^L$$

$$w^L = x^L - (r^L + d) k^L$$

$$(g_k{}^L + d) = s(r^L + d)$$

$$c^L = x^L - (g_k{}^L + d) k^L$$

with $g_x{}^L$ as the exogenous growth rate of labor productivity and $g_p{}^L$ as the exogenous growth rate of capital productivity. As previously mentioned, the Marx-biased technical change implies that $g_x{}^L > 0$ and $g_p{}^L < 0$.

In the follower country, economic growth is described by:

$$x^F = x_0{}^F(1 + g\,x^F)^t.$$

$$p^F = p_0{}^F(1 + g_p{}^F)^t.$$

$g_x{}^F = g_x{}^L + \psi a$, where $\psi = f(g_K^F) > 0$ if $g_K^F > g_K^L$, and $\psi = f(g_K^F) \leq 0$ if $g_K^F \leq g_K^L$.
$g_p{}^F = g_p{}^L + \theta b$, where $\theta = f(g_K^F) > 0$ if $g_K^F > g_K^L$, and $\theta = f(g_K^S) \leq 0$ if $g_K^F \leq g_K^L$.

$$w^F = (1 - \pi)x^F.$$

$$w^F = x^F - (r^F + d)k^F.$$

$$(g_k{}^F + d) = s(r^F + d).$$

$$c^F = x^F - (g_k{}^F + d)k^F.$$

The exogenous variables of the model are the initial techniques in the leader $(x_0{}^L, p_0{}^L)$ and in the follower countries $(x_0{}^F, p_0{}^F)$, the depreciation rate (d), the profit share ($\pi^L = \pi^F = \pi$), the capitalist saving rate ($s^L = s^F = s$), and the growth rates of capital (gp^L) and labor productivities (gx^L) in the leader country.

The endogenous variables are the techniques in the leader (x^L, p^L) and in the follower country (x^F, p^F), the net profit rates in the leader (r^L) and in the follower (r^F), the capital accumulation in the leader (g_K^L) and follower country (g_K^F), the social consumption per worker in the leader (c^L) and in the follower country (c^F), the terms of catching up for labor productivity (ψ) and capital productivity (θ), and the growth rates of capital productivity ($g_p{}^F$) and labor productivity ($g_x{}^F$) in the follower country.

In the initial period, the productivity of labor is higher and the productivity of capital is lower in the leader country. The average real wage is higher and the profit rate is lower in the leader country. For similar profit share, the profit rate is higher in the follower country due to higher capital productivity. Under the assumption that the capitalists' saving rate is the same in both countries, capital accumulation is greater in the follower than in the leader due to the higher profit rate. Conversely, social consumption is greater in the leader than in the follower country. Figure 3 represents the model in the initial period.

A process of catching up occurs when capital accumulation is greater in the follower country, in this case $g_x{}^F > g_x{}^L$ and $g_p{}^F < g_p{}^L$. Moreover, the pattern of technical change in the follower country takes the Marx-biased form. It will reduce the differences in the productivities of labor and capital, in the capital-labor relation, in the average real wage, in the profit rate, in capital accumulation, and in the social consumption per worker between the countries.

The path of the profit rate depends on technical change and the distribution of income. The combination between a Marx-biased technical change and a constant wage share results in a falling profit rate. The process of catching up hinges on the rate of capital accumulation, which in turn is determined by the profit rate and the saving rate. The decline of capital productivity in the follower country reduces the profit rate and capital accumulation.

The increasing capital/labor ratio in the follower country through mechanization and industrialization may not eliminate the differences in labor productivity in relation to the leading country. There is the possibility, as our results show, of a higher velocity of catching up in capital productivity than in labor productivity. If capital productivity falls very rapidly in the

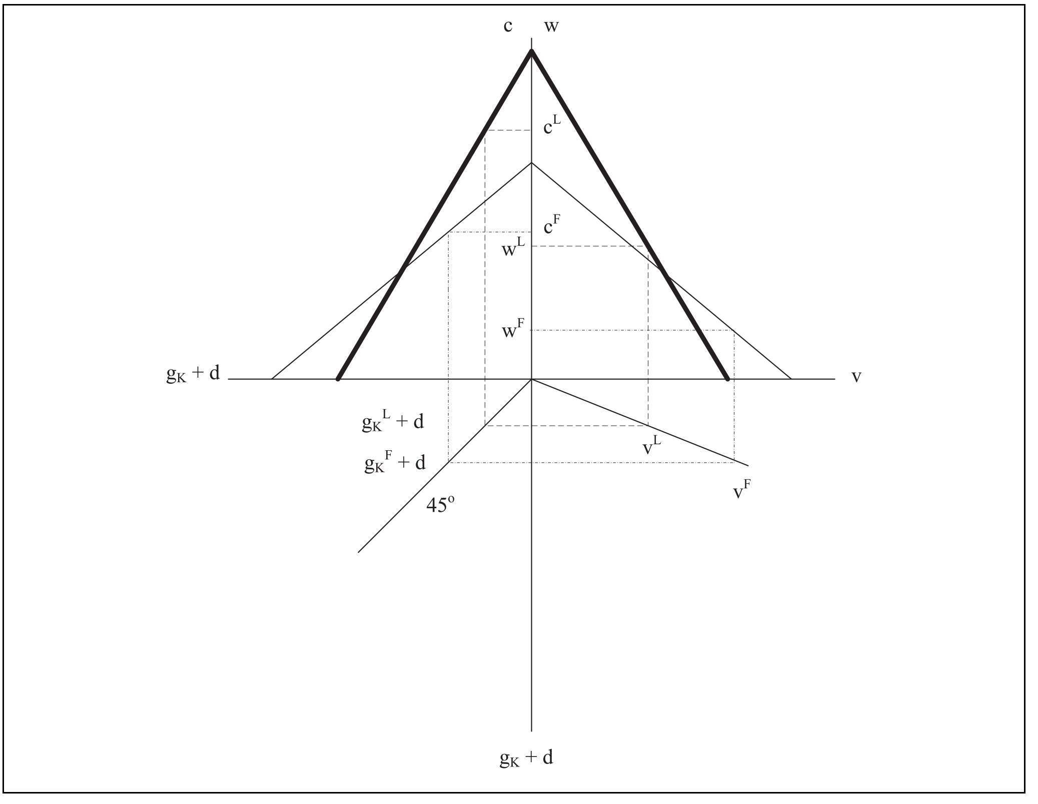

Figure 3. The classical-Marxian model of catching up in the initial period. The follower country, represented by the thin line, has lower labor productivity and higher capital productivity than the leader, represented by the thicker line. For similar income distribution and saving rate, in the initial period the follower has lower real wage, $w^F < w^L$, higher profit rate, $v^F > v^L$, and capital accumulation, $g_K^F + d > g_K^L + d$, and lower social consumption per worker, $c^F < c^L$, than the leader.

follower country, catching up in labor productivity may halt due to the decline in the profit rate and in capital accumulation.

Small changes in the hypotheses that allow for capital accumulation in the leader country to be higher than in the follower will result in a process of falling behind. Two possibilities exist for how this can happen: (1) when the savings rate in the leader country is higher than in the follower country, and (2) when the profit rate is higher in the leader country.

The velocity of the process of catching up may decline when the growth of capital productivity in the leader country is positive. In this case, *ceteris paribus*, the profit rate and capital accumulation will rise in this country. From a historical perspective, these periods occur when a new technological wave is starting. Perez and Soete (1988) and Perez (2003) pointed out that backward countries have a window of opportunity to catch up, but the possibility of falling behind also exists.

4.2. Patterns of economic growth

In this section, we investigate some of the stylized facts that support the main hypotheses of our model. Appendix 1 presents the data source and describes the methodology to compute the data set. Despite the measurement problems associated with the comparison of international data,

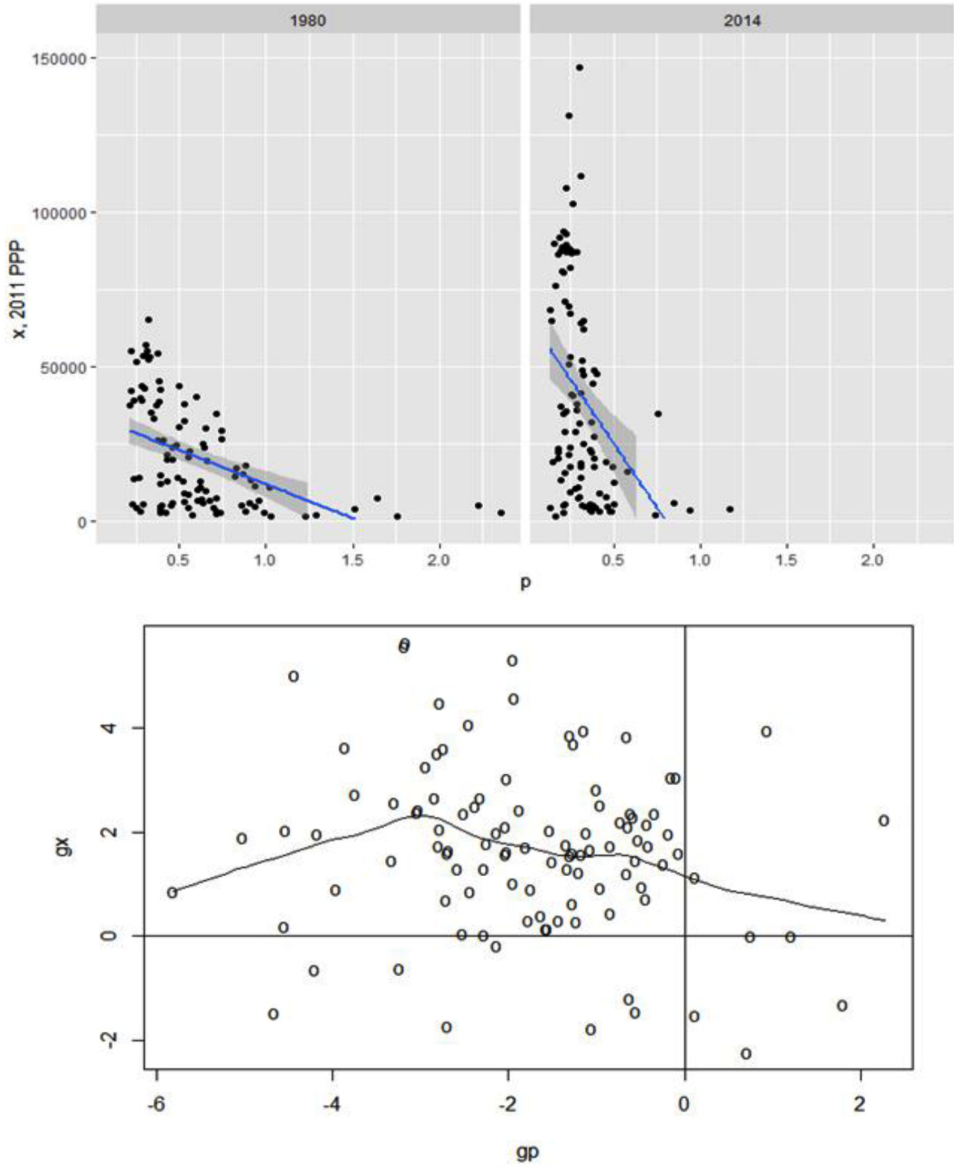

Figure 4. The capital and labor productivity points (p, x) and the compound growth rates of capital productivity and labor productivity (g_p, g_x) between 1980 and 2014.
Source: See Appendix 1.

our results are consistent with the empirical literature that employs data from the national statistical offices.

The upper panel of figure 4 plots labor and capital productivities and shows the linear fit between them for 103 countries in 1980 and 2014, respectively. If there is a tendency in the course of economic development for countries to display a path of declining capital productivity

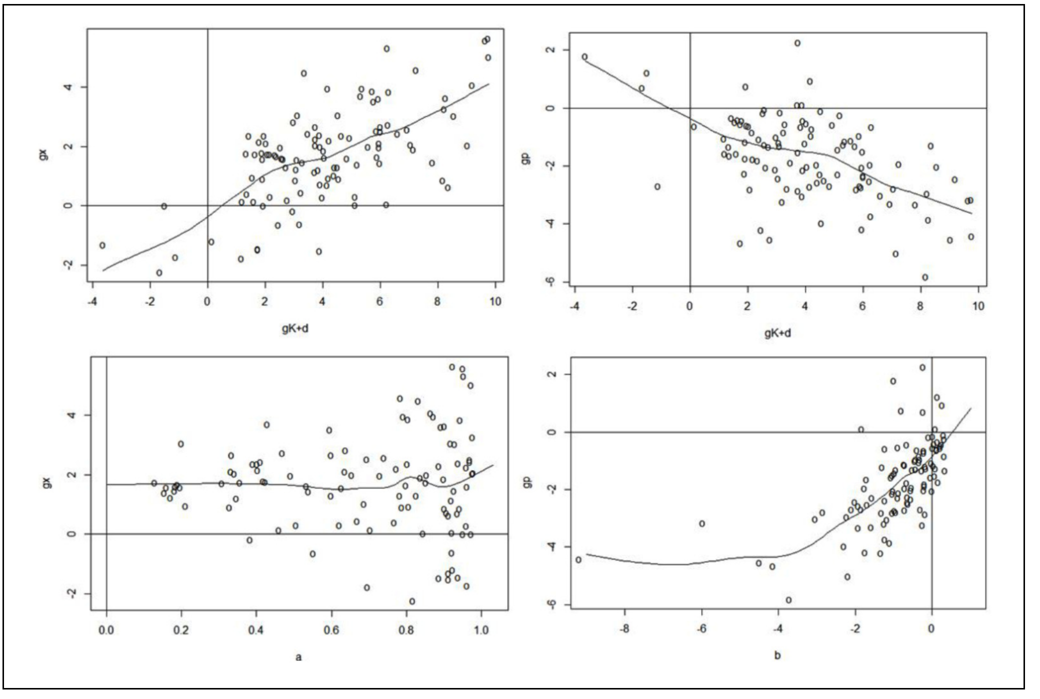

Figure 5. The relationships between capital accumulation and the growth rate of labor productivity, ($g_K + d$, g_x), between capital accumulation and the growth rate of capital productivity, ($g_K + d$, g_p), between the gap in labor productivity in 1980 and the growth rate of labor productivity, (a, g_x), and between the gap in capital productivity in 1980 and the growth rate of capital productivity, (b, g_p), 1980–2014.
Source: See Appendix 1.

and rising labor productivity, we would expect a clockwise movement in the fit between labor and capital productivities. The linear fit moves in the expected direction, and in 2014 it is much steeper than in 1980, revealing that there is a tendency for national economies to follow a path of declining capital productivity and rising labor productivity. Certainly, there are variations in the paths that national economies follow in the process of economic development. However, the data display a clear movement toward lower capital productivity and higher labor productivity.

The bottom panel of figure 4 displays the data on the compound growth rates of capital productivity and labor productivity between 1980 and 2014. The data are fitted using local regression (Cleveland 1993). It is a nonparametric technique that calculates a weighted least square fit to the data at each point on a grid, with weights that decline sharply with the distance of the data point from the grid point. Despite the presence of observations in other quadrants, there is a strong tendency for the points to cluster in the quadrant corresponding to a negative growth rate of capital productivity and a positive growth rate of labor productivity. It supports the hypothesis that countries tend to follow a Marx-biased pattern of technical change in the process of economic development.

Figure 5 investigates empirically the hypotheses employed in Equations 8 and 9. The top-left panel exhibits the data on capital accumulation and the compound growth rate of labor productivity computed between 1980 and 2014 and the estimated local regression fit. A linear positive association between capital accumulation and labor productivity growth exists. The top-right panel displays the data on capital accumulation and the compound growth rate of capital

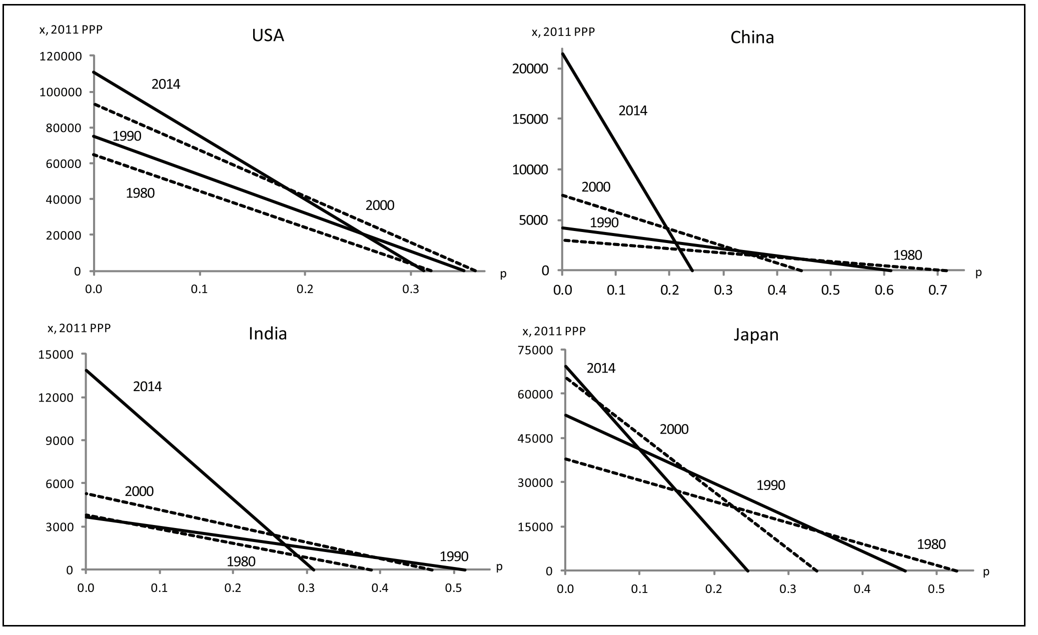

Figure 6. The growth-distribution schedules for the United States, China, India, and Japan, 1980, 1990, 2000, and 2014.
Source: See Appendix 1.

productivity for the 1980–2014 period and the estimated local regression fit, and shows a linear negative association between capital accumulation and capital productivity growth. Interestingly, a higher capital accumulation is associated with a higher and positive growth of labor productivity and a lower and negative growth of capital productivity. These results are consistent with our model's assumptions.

The bottom-left panel presents the data on the gap in labor productivity in 1980 and the compound growth rate of labor productivity between 1980 and 2014. The estimated local regression fit would suggest the lack of a relationship between labor productivity growth and the gap in labor productivity in the initial period. However, the growing spread of data around the estimated local regression fit as the gap in labor productivity expands reveals that while some countries may benefit from their backwardness, others with a similar status do not take advantage of it (Gerschenkron 1962).

The bottom-right panel exhibits the data on the gap in capital productivity in 1980 and the compound growth rate of capital productivity between 1980 and 2014. Most countries are in a quadrant with a negative growth rate of capital productivity and a negative capital productivity gap with respect to the leader. It indicates that most countries exhibit a higher capital productivity than the leader and catch up with a negative growth rate. In summary, the stylized facts are consistent with our model's assumptions.

5. Technical Change and Catching Up in China, Japan, and India

The movements of the growth-distribution schedule reveal the pattern of technical change. Figure 6 illustrates the growth-distribution schedules for the United States, China, Japan, and India in 1980, 1990, 2000, and 2014.

For the United States, there was a Harrod-neutral technical change between 1980 and 2014.[5] However, it is possible to identify two stages of technical change in the economy of the United States. First, between 1980 and 2000 there was an increase in labor productivity and capital productivity. It may reflect the effects of the adoption of information and communication technologies. Second, a Marx-biased technical change occurred between 2000 and 2014. This result is consistent with Duménil and Lévy's (2016) view that after 2000 the United States started on a trajectory consistent with Marx's conception of technical change.

China exhibited the Marx-biased pattern as the only form of technical change in the 1980–2014 period, in which there was continuous declining capital productivity and rising labor productivity. In the Japanese economy, the pattern of technical change is consistent with the capital-using, labor-saving Marx-bias for the 1980–2014 period. Between 2000 and 2014, the decline in capital productivity was much faster than the rise in labor productivity. For India, the Marx-biased technical change is the dominant pattern in the period 1980–2014, with two stages of technical change. First, between 1980 and 1990, labor productivity declined and capital productivity expanded. Second, labor productivity rose and capital productivity declined between 1990 and 2014.

Figure 7 shows the paths of labor productivity and capital productivity in China, Japan, and India in relation to the United States between 1980 and 2014. There are four interesting results. First, China, Japan, and India had lower labor productivity and higher capital productivity than the United States in 1980, which conforms with our hypothesis. Second, in the process of catching up, there was a rise in labor productivity and a decline in capital productivity in relation to the United States. Third, the process of catching up in China started in the early 1980s and in India in the late 1980s. In China, this period is marked by the beginning of market-oriented reforms where privatization of agricultural production and small/medium public enterprises took place (Li 2017). In the case of Japan, the process of falling behind started in the mid-1990s when labor and capital productivities declined in comparison with the United States. Fourth, capital productivity in China, Japan, and India fell below the level observed in the United States. The velocity of catching up in capital productivity was higher than in labor productivity for China, Japan, and India.

The countries' experiences reveal that in the process of catching up, there is a tendency for technical change to follow the capital-using, labor-saving Marx-bias pattern. The process of catching up involves the transfer of capital-intensive technology from the leader to the follower countries through capital accumulation. Substantial efforts are necessary in terms of capital formation to overcome the relative backwardness of the follower countries.

However, there seem to be important aspects that are difficult to eliminate and that may partially explain the lower velocity of catching up in labor productivity than in capital productivity. These aspects are internal and external to the firms. Within the firms, differences in the scale of production exist, both in management practices and in workers' capacity to learn and operate new machines. External to the firms, differences exist in public infrastructure, education of workforce, capacity for innovation, and the institutional framework in which the firms operate.

6. Profit Rate and Catching Up in China, Japan, and India

Marx (1981: 318) suggested that the ''growth in the constant capital, in relation to the variable, must necessarily result in a gradual fall in the general profit rate, given that the rate of surplus-

[5]Capital productivity declined 0.07 percent annually between 1970 and 2014.

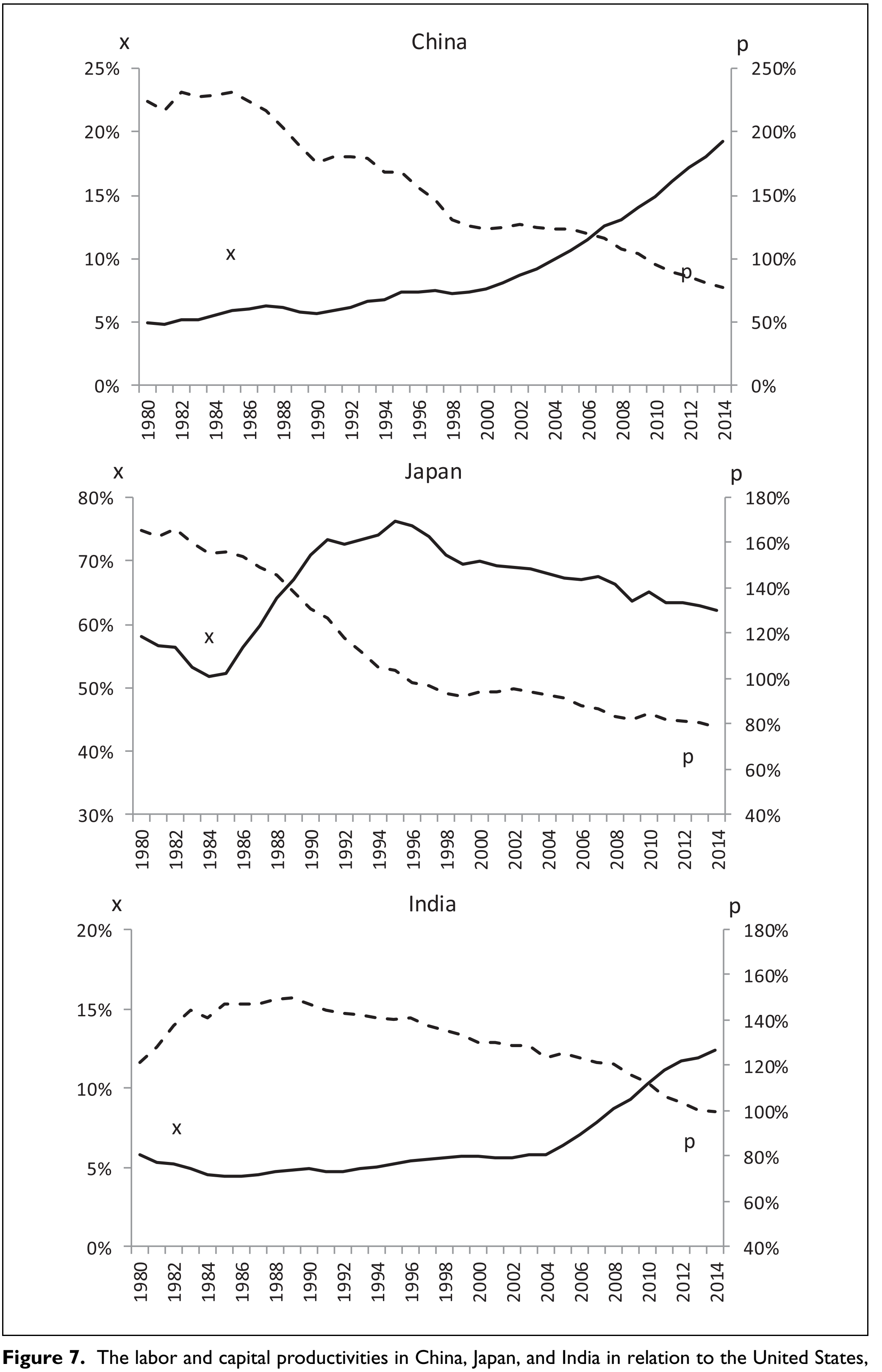

Figure 7. The labor and capital productivities in China, Japan, and India in relation to the United States, 1980–2014.
Source: See Appendix 1.

value… remains the same.'' The conception that profit rate reflects the movements of capital productivity and profit share resembles Marx's analysis of the profit rate in terms of technology and distribution. The rate of profit is one of the determinants of capital accumulation. However, there is a feedback mechanism. Rapid capital accumulation may reduce capital productivity such that, when combined with a relatively stable wage share, it may lower the profit rate.

Figure 8 displays the profit rate and the productivity of capital for the United States, China, Japan, and India during the 1980–2014 period. The profit rate in the United States was trendless between 1980 and 2014. It presented a cyclical movement that increased between 1982 and the late 1990s, declined until 2008, and then somewhat expanded. The movements reflected the capital productivity path.

The profit rate in China showed a declining tendency that mirrors the evolution of its capital productivity. Japan also exhibited a declining tendency in the profit rate despite its relative stability during the 1980s. Its movements also replicated closely the path of capital productivity. In India, the profit rate expanded until the mid-2000s due to rising profit share, and then the profitability declined, driven by falling capital productivity. The capital productivity rose until the late 1980s and thereafter began to fall. The increase in profit share played an important role in the rise of the profit rate in India. Basu and Das (2018) found that the profit rate in India's organized manufacturing sector increased between 1982 and 2013 due to the rising profit share.

The profit rate and the productivity of capital in the United States were smaller than in the follower countries when the catching-up process started, which is explained by the difference in capital productivity between the followers and the leader at the beginning of the process. The profit rate and capital productivity declined at a fast pace in China and Japan. The profit rate in Japan was lower than in the United States in the mid-1990s. The profit rate in China was lower than in the United States in the late 2000s. These results are consistent with Li's (2017) study, which found a lower profit rate in China and Japan in comparison with the United States in 2015. The profit rate in India was higher than in the United States. However, capital productivity in India was lower than in the United States in 2014.

In the case of China, Japan, and India, capital productivity declined rapidly to a level inferior to the capital productivity value of the United States. Thus, the process of catching up in these countries will have to follow a path that stabilizes capital productivity while raising labor productivity. The fall of capital productivity and therefore of profit rate may inhibit the process of catching up. However, capital accumulation may respond differently to the falling profit rate according to the structures of capital ownership, with different impacts on economic growth. Li, Yue, and Zhao (2009) showed that state-owned firms in China have easier access to long-term debt and consequently they have higher long-term investment.

7. Capital Accumulation and the Process of Catching Up and Falling Behind

Countries in the process of catching up follow a pattern of rising labor productivity and falling capital productivity typical of mechanization. According to our model, a necessary condition for catching up is that capital accumulation in the follower country is greater than in the leader. Capital accumulation is a function of both saving and profit rates.

Figure 9 displays the investment rates, a proxy for the saving rates, of the United States, China, Japan, and India in the period of study. The United States had an average investment rate slightly above 25 percent between 1980 and 2007, falling close to 20 percent after the 2008 crisis. China had an impressive increase in the investment rate, moving from 15 percent in 1980 to above 45 percent in the 2010s. The investment rate in China was smaller than in the United

Figure 8. The profit rate and capital productivity in the United States, China, Japan, and India, 1980–2014.
Note: The thin line is the value for the United States.
Source: See Appendix 1.

States until the mid-1990s, but then surpassed the United States after 2000. In Japan, the investment rate was above 30 percent until the late 1990s, and then it declined to a level similar to the United States. The investment rate in India was below 20 percent until the late 1990s, when it started to rise, reaching more than 30 percent after the mid-2000s.

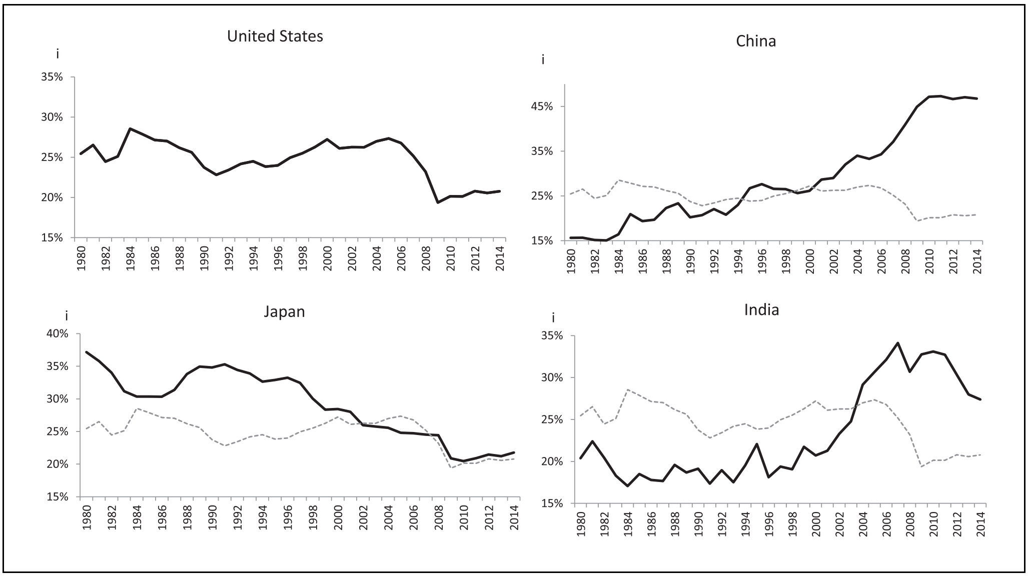

Figure 9. Investment rate in the United States, China, Japan, and India, 1980–2014.
Note: The thin line is the value for the United States.
Source: See Appendix 1.

Figure 10 plots the capital accumulation for the United States, China, Japan, and India during the 1980–2014 period. The capital accumulation in China was higher than in the United States for the whole study period. In Japan, the capital accumulation was superior to the United States until the mid-1990s. Capital accumulation in India was greater than in the United States after the early 1990s.

These were the periods in which the follower countries were able to catch up with the leader. The higher capital accumulation resulted from a combination of a larger profit rate and higher investment rate, particularly in the early stages of the process. The rapid accumulation may have reduced capital productivity and the profit rate, as the experiences of China, Japan, and India attest. In this case, catching up depends on raising the investment rate. It could bring a further decline in capital productivity and in the profit rate that may put the process in jeopardy.

8. Concluding Remarks

This article presents a model in the classical-Marxian tradition that helps to better understand the phenomena of catching up and falling behind. The model pinpoints the macroeconomic variables that drive the catching-up process, shedding light on the discussions about the different economic performances between nations. Herein, we have investigated some stylized facts associated with our model and the economic trajectories of China, Japan, and India with respect to the United States from 1980 to 2014.

The results reveal that when the process of catching up occurred, the follower countries exhibited a Marx-biased technical change. The rapid process of mechanization in these countries caused a fall in the profit rate to a level similar to or lower than the Unites States. This result is consistent with Libman, Montecino, and Razmi (2017). They pointed out that the higher the capital productivity, and therefore the profit rate, the higher the probability of an accelerated capital stock growth. In Japan, this process stopped through a decline in capital accumulation.

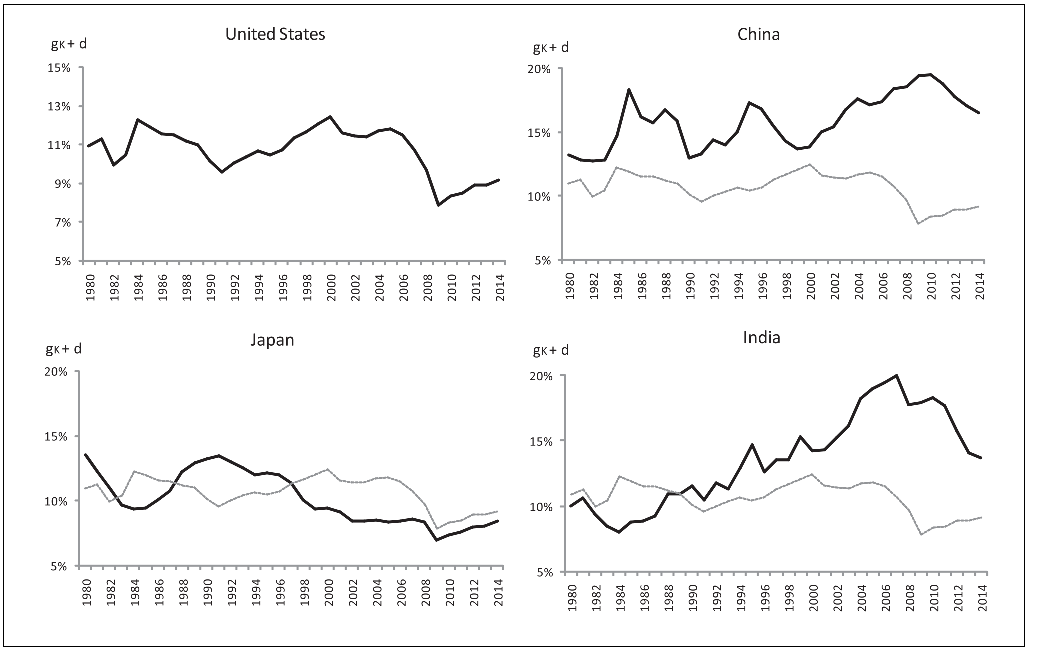

Figure 10. Capital accumulation in the United States, China, Japan, and India, 1980–2014.
Note: The thin line is the value for the United States.
Source: See Appendix 1.

The larger profit rate explained the robust mechanization in the early stages of the process. Fast capital accumulation diminishes capital productivity and the profit rate. Then, the success in catching up must hinge on raising the saving and investment rates. It may further reduce capital productivity and the profit rate, putting the process at risk, which seems to be the case in China and India. Li (2017: 401) noted that ''if China were to follow essentially the same economic laws as in other capitalist countries (such as the United States and Japan), a decline in the profit rate would be followed by a deceleration of capital accumulation, culminating in a major economic crisis.'' The growth in capitalist economies, whether as the leader or the follower, as Basu and Das (2018) pointed out, is related to profitability.

Our results indicate that catching up is a challenge for emerging countries. A substantial effort is necessary to boost accumulation to fight backwardness. However, these efforts reduce the profit rate and the incentives for capital accumulation. Our results show a higher velocity of catching up in capital productivity than in labor productivity. The difference in the velocity of catching up may be related to differences in the scale of production and workers' capacity to learn. Factors external to the firms, such as differences in public infrastructure, education, capacity for innovation, and the institutional framework, may play a role. The question of what accounts for the differences in capital accumulation across follower countries is open and remains an important research topic for the developing nations.

Moreover, as Amsden (2001) argued, it is a demanding task to replicate the growth path of the United States. The United States combines a large amount of natural resources and physical and human capital with a high capacity for generating technical and institutional innovations. It may explain the relative stability of the capital productivity and profit rate in the United States during the period of study. The process of catching up requires that the spread of technology be associated with institutional change in the follower country.

Appendix 1: Data Set

This appendix presents the data source and describes the methodology employed to organize the data set. The data set is the Extended Penn World Tables organized by Marquetti (2017) from the Penn World Table (PWT) version 9.0 (Feenstra, Inklaar, and Timmer 2015) and other sources. Labor productivity is the ratio between the real GDP at constant 2011 PPP (output side) and the number of workers in the PWT version 9.0. Capital productivity is the ratio between the GDP at current PPP and the current capital stock. The profit rate is the multiplication of capital productivity and profit share computed from the PWT version 9.0. The real wage is the multiplication of labor productivity and the wage share. Capital accumulation is the ratio between capital stock at constant PPP and the investment at constant PPP. The standardized fixed capital stock is obtained by the perpetual inventory method (PIM). The PIM procedure employed follows Hulton and Wycoff (1981). The depreciation takes a geometric form. Hulton and Wycoff calculated the rate of depreciation (d) with the expression ($d = R/T$), where R is the factor that defines the degree of declining balance due to depreciation, and T is the average asset life. The average value found by Hulton and Wycoff for R was 1.65 for equipment categories and 0.91 for structure categories. The R employed in this study was 1.05. It was calculated considering that equipment categories represent 20 percent and structure categories represent 80 percent of the gross capital formation. The asset life considered was eighteen years, so the depreciation rate was 5.834 percent. The net capital stock was computed using the expression $K_t = (1 - 0.05834/2)I + \sum_{i}^{T} (1 - 0.05834)^{(T-i)} I_{T-i}$, $i = 2, \ldots, 14$, where I is the investment series calculated by the multiplication between the share of gross capital formation at current PPPs and the output-side GDP at current PPPs. The investment series was then deflated to real PPPs. This procedure considers that new assets are placed in service at midyear. Thus, depreciation on these assets in year 1 is equal to half of the depreciation on the other assets.

Appendix 2: An Analysis for Equations 8 and 9

Catching up requires that the growth rate of labor productivity in the follower country is greater than the growth rate of labor productivity in the leader and that the growth rate of capital stock in the follower country is greater than in the leader. Equation 8 expresses the growth rate of labor productivity in the follower country as:

$$g_x{}^F = g_x{}^L + \psi a,$$

where: $\psi = f(g_K^F) > 0$ if $g_K^F > g_K^L$, and $\psi = f(g_K^F) \leq 0$ if $g_K^F \leq g_K^L$.

The condition for catching up in labor productivity is obtained from Equation 8. We consider the Taylor series of ψ, developed around the point g_K^L: $\psi = f(g_K^F) = f(g_K^L) + f'(g_K^L).(g_K^F - g_K^L) + \ldots$. Assuming for simplicity that $f(g_K^L) = 0$ and that the terms of f'' and higher are closer to zero, we obtain $\psi = f(g_K^F) = f'(g_K^L).(g_K^F - g_K^L)$. Then, if f is a positive function of g_K^L, that is $f'(g_K^L) > 0$, we have $\psi > 0$ if $(g_K^F - g_K^L) > 0$ and $\psi < 0$ if $(g_K^F - g_K^L) < 0$. As $x^F \to x^L$, the value of a tends to zero, since $\lim_{x^F \to x^L} a = (1 - \frac{x^F}{x^L}) = 0$; therefore, $g_K^F \to g_K^L$.

There is a simple proof for the assumption that $f'(g_K^L) > 0$. In the case of catching up, from Equation 8 we have: $g_x{}^F - g_x{}^L = \psi a > 0$, where $a > 0$; therefore, $\psi = f(g_K^F) = f'(g_K^L).(g_K^F - g_K^L) > 0$. If $(g_K^F - g_K^L) > 0$, then $f'(g_K^L) > 0$ in order to have $\psi > 0$. In the case of falling behind, $g_x{}^F - g_x{}^L = \psi a < 0$, where $a > 0$; therefore, $\psi = f(g_K^F) = f'(g_K^L).(g_K^F - g_K^L) < 0$. If $(g_K^F - g_K^L) < 0$, then $f'(g_K^L) > 0$ in order to have $\psi < 0$.

The growth rate of capital productivity in the follower country is expressed by equation 9:

$$g_p{}^F = g_p{}^L + \theta b,$$

where: $\theta = f(g_K^F) > 0$ if $g_K^F > g_K^L$, and $\theta = f(g_K^S) \leq 0$ if $g_K^F \leq g_K^L$.

In the present case, $\theta = f(g_K^F) = f(g_K^L) + f'(g_K^L).(g_K^F - g_K^L) + \ldots$. Considering that $f(g_K^L) = 0$ and the terms f'' and higher are close to zero, we obtain $\theta = f(g_K^F) = f'(g_K^L).(g_K^F - g_K^L)$. On the condition that f is a positive function of g_K^L, $f'(g_K^L) > 0$, the results are $\theta > 0$ if $(g_K^F - g_K^L) > 0$ and $\theta \leq 0$ if $(g_K^F - g_K^L) \leq 0$. As $p^F \to p^L$, the value of b tends to zero since $\lim_{p^F \to p^L} b = (1 - \frac{p^F}{p^L}) = 0$; therefore, $g_K^F \to g_K^L$.

We can prove the assumption that $f'(g_K^L) > 0$. In the case of catching up, from Equation 9, we have $g_p{}^F - g_p{}^L = \theta b < 0$, where $b < 0$; therefore, $\theta = f(g_K^F) = f'(g_K^L).(g_K^F - g_K^L) > 0$. If $(g_K^F - g_K^L) > 0$, then $f'(g_K^L) > 0$ in order to have $\theta > 0$. In the case of falling behind, $g_p^F - g_p{}^L = \theta b < 0$, where $b < 0$; therefore, $\theta = f(g_K^F) = f'(g_K^L).(g_K^F - g_K^L) < 0$. If $(g_K^F - g_K^L) < 0$, then $f'(g_K^L) > 0$ in order to have $\theta < 0$.

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