**A neo-Kaleckian model of skilled-biased technological change and income distribution**

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**Abstract:** This article proposes a macrodynamic model that takes into account the joint determination of intra-working class income distribution and knowledge-intensive technological change. Our model highlights two opposing effects of technological change at play: (i) Technological innovation promotes a positive structural change and hence boosts net exports and output growth; (ii) Technological change, on the other hand, disproportionally affects unskilled workers, which worsens the intra-working class income distribution and slows down economic growth. Therefore, our model demonstrates that the net impact of technological change on capital accumulation and output growth is ambiguous and hence is a parametric question. Lastly, we show that income transfer and public investments in higher education may be of paramount importance to alleviate the unwanted effects of a contractionary wave of technological change and so promote a sustained economic recovery.

**Keywords:** Technological change, income distribution, education

**JEL Classification:** J31, I24, O11, O33

1. **Introduction**

In Solow’s seminal work (1957) technological change increases output while leaving the marginal productivity of the given inputs unchanged. In other words, technological change is factor-neutral. However, empirical evidence for advanced countries has challenged this conceptualization, as they show that technological change has a ‘factor-biased’ attribute that favors skilled workers over unskilled workers (Autor et al., 1998; Goldin and Katz, 2008; Katz and Margo, 2014; and Katz and Murphy, 1992)[[2]](#footnote-2).

The so called skill-biased technological change (SBTC) is the idea that new technologies, changes in production process, or changes in the organization of work are more complementary to skilled workers, so that shifts in the level of technological capabilities of the economy increases the demand for skilled relative to unskilled labor (Violante, 2008). Tinbergen (1974) introduced the notion of a race between technology and education, in which skill-biased technological change has a negative impact for income distribution. Goldin and Katz’s book *The Race between Education and Technology* (2008)provides a unified framework to understand the supply and demand for skilled workers and their impact on income inequality in the U.S., and even though the authors argue that other elements, such as institutions and a fall in the supply of skilled workers affected income inequality, SBTC remains one of the most important factors behind the recent rise in income inequality across different educational groups (see also Acemoglu, 2002; and Acemoglu and Autor, 2012). In this sense, Cozzens (2008) argues that traditionally innovation policies tend to increase inequality and that leaving the process of diffusion of new technologies to market mechanisms does not guarantee that the measures taken also meet the needs of the poor. Therefore, the author suggests that, to prevent adverse effects of technological progress, innovation policies should take into account the social dynamics and the impacts of innovation on inequality.

Thus, while technological change is, on the one hand, a source of economic development, on the other hand it has the potential to increase gaps in wealth and well-being between individuals and groups, thereby partially or totally undermining the positive effects of innovation on the economy. There is a large body of empirical literature strongly suggesting that greater personal income inequality adversely affects output growth (see Alesina and Rodrik, 1994; Barro, 2000; Clarke, 1995; Li and Zou, 1998; Perotti, 1996; and Persson and Tabellini, 1994). Alternatively, another tradition in the growth literature that can be traced back to the works of Kalecki, Keynes and Steindl argues that the redistribution of income from the poorer to the richer may lead to economic stagnation (Amadeo, 1986; Dutt, 1984). It is argued that since low-income households have a higher propensity to consume than higher-income households, greater income inequality reduces aggregate consumption, lowers expected profits and hence discourages capital accumulation[[3]](#footnote-3). More recently, Blecker (2016) states that while greater inequality is more likely to boost aggregate demand in the short run, such a positive effect is more likely to be reversed as time goes by[[4]](#footnote-4). Therefore, the net impact of technological change on capital accumulation remains unclear. While in one hand it boosts non-price competitiveness and the level of economic activity, on the other hand it may deteriorate income distribution, thus affecting negatively aggregate demand and capacity utilization.

In light of the above considerations, our work contributes to the literature by setting forth a neo-Kaleckian theoretical framework that integrates the joint determination of technological change and income distribution across different educational groups in an open developing economy[[5]](#footnote-5). The model consists of a richer foreign country that pushes forward the innovation frontier and a poorer home country that lags behind. On the basis of time, our model is divided into short- and medium-run. In the short-run analysis, we explore the effects of technological change and income distribution on the level of capacity utilization that guarantees the equilibrium in the goods market. We conclude that, due to the differential saving propensities assumption, a higher wage share in income of skilled workers in detriment of the wage share of unskilled workers reduces capacity utilization and capital accumulation; another important result is that a more sophisticated, technology-intensive productive structure improves non-price competitiveness, thus increasing net exports, capacity utilization and accumulation. In the medium-run analysis, we investigate the mutual determination of intra-working class income distribution and technological change. Our model shows the emergence of two opposing effects. On the one hand, technological innovation promotes a positive structural change and hence spurs output growth. On the other hand, technological change disproportionally favors skilled-workers, which worsens the intra-working class income distribution and slows down economic growth. Therefore, our model shows that the net impact of a knowledge-intensive technological change on capital accumulation and output growth can go either way and hence is a parametric question.

The remainder of this article consists of three more sections. In section 2 we advance the short-run model. Section 3 presents the medium-run dynamical analysis between technical change and intra-working class income distribution. In the last section, we conclude.

1. **The structure of the model in the short run**

We assume an open economy that produces a single good that can be used for both investment and consumption. The global economy consists of basically two different countries: a richer foreign country that takes the lead in innovation activities and a poorer home country that lags behind. Domestic firms operate with excess capacity in oligopolistic markets and only use domestic capital in the production process. Production is carried out according to a fixed-coefficient technique that uses a combination of two factors of production, domestic capital and labor, which, in turn, consists of skilled and unskilled labor. Skilled workers are those that constitute the share of the labor force with a college degree or above. Since it is plausible to assume that the majority of the labor force in developing does not have any sort of educational attainments, we state that the case of excess unskilled labor capacity prevails in domestic firms.

We define the rate of capacity utilization of the domestic capital stock (*u*) as the effective output-potential output. The production function can be defined as:

where is the effective output, and are unskilled and skilled employed labor, is the stock of domestic capital (henceforth, ‘capital’), and are labor productivity for unskilled and skilled workers, denotes the potential output-capital ratio. Assuming that equals unity for simplicity, total output is given by .

There are two classes in the economy, capitalists and workers. Capitalists earn only profits and save all their income. Workers are divided into skilled and unskilled. The latter earn only wages and consume all their income, whereas the former earn a higher wage due to the skill premium which allows them to save a fraction of their income. Thus, capitalists define the price level by setting a markup factor, , over unitary labor costs:

where , , and and are the nominal wages earned by unskilled and skilled workers respectively, which implies that . It is plausible to assume that and are greater than unity as both nominal wages and labor productivity of skilled workers are usually higher. According to human capital theory, education increases labor productivity (Becker, 1964). There is a vast empirical literature suggesting that investments on education tend to have a considerable and positive effect on productivity (see Rycx et al. 2015 for a survey). In addition, there is also some solid empirical evidence accounting for the positive impact of education on wages, showing a considerable difference between high- and low-educated workers (Card 1999; Harmon et al., 2003; Piketty and Saez, 2003).

By equation (2), and assuming that domestic income is constituted by the sum of total wages and profits, we can define the profit share of income as follows:

From equation (3), the wage share of skilled workers and unskilled workers can be defined as:

where and are the wage shares of skilled and unskilled workers, respectively. Simply stated, the higher the productivity differential (wage differential), the lower (higher) the share of skilled workers. In addition, both equations (4.a) and (4.b) show that, for a constant mark-up , the wage share of skilled and unskilled workers are inversely related.

Equilibrium in the goods market in the short run arises from changes in capacity utilization. Since domestic firms operate with excess capacity, total output per unit of capital is determined by the aggregate effective demand that equals the sum of consumption per unit of capital (*c*), investment per unit of capital (*i*) and net exports per unit of capital (), as follows:

The rate of investments per unit of capital depends on autonomous investment per unit of capital (), and the rate of capital utilization (accelerator). Therefore:

Equation (6) is a neo-Kaleckian investment function[[6]](#footnote-6), in which captures the ‘animal spirit’ of capitalists (or the state of long run expectations). As aforementioned, unskilled workers do not save, skilled workers save a constant fraction of their income, and capitalists’ saving rate is equal to unity. It means that a redistribution of income from skilled workers and/or capitalists to unskilled workers increase consumption spending.[[7]](#footnote-7) Therefore, consumption per unit of capital can be defined as:

Lastly, net exports per unit of capital depend positively on the developed economy’s capacity utilization of foreign capital stock, and negatively on the domestic rate of capital utilization and , respectively:

where and are the exports and imports coefficients, respectively. Note that, for convenience, we consider that the impact of real exchange rate variations on net exports is negligible.

It is known that both and can be interpreted as a proxy for the non-price competitiveness in foreign trade of domestically produced goods. The magnitude of both parameters and reflects disparities between countries with respect to factors determining the demand for a country’s exports and imports, such as technological capabilities, product quality, stock of knowledge, and consumer preferences, for instance.[[8]](#footnote-8) Having said that, we define and as function of the relative technological capability of the home country:

where are constants, and denotes the technological gap defined as the ratio of the level of the home country’s technological capabilities to the level of the foreign country’ technological capabilities. Since it is assumed that the foreign country is a developed and diversified economy which takes the lead in technological innovations while the home country lags behind, we must necessarily have .

In the short run we assume that , , , , , , , and are given. From equations , and then solving for , we obtain the equilibrium level of domestic capacity utilization:

for Keynesian stability, we assume that the denominator of equation (11) is positive, which is equivalent to:

By plugging equation (11) into (6) we find the equilibrium rate of capital accumulation:

Equation (11) has some common results in this literature. For instance, a rise in the “animal spirit” () or a fall in the saving rate of skilled workers have a positive impact on capacity utilization. Moreover, redistribution from unskilled to skilled workers has a negative effect in capacity utilization. As the former has a lower saving rate (here assumed to be equal to zero) than the latter, aggregate demand falls when the income share of unskilled workers is reduced; more formally, from equation (12), we have . It can also be observed that an increase in the country’s relative technological capabilities, , promotes a positive structural change towards a more complex and diversified economy, thus improving the non-price competitiveness of domestic goods and, consequently, the country’s net exports; in formal terms, by equation (12), we obtain .

1. **Medium-run analysis**

Even though it is impossible for a country that does not issues the international currency to finance a growing ratio of current account deficit to GDP indefinitely, it is plausible to admit a continued mismatch between exports and imports for a certain period of time. Therefore, in the medium-run analysis, we do not impose any constraints on the trade balance of the home country. In the medium run we also assume that , , , , , , and can vary. To keep focus and maintain the model as simple and tractable as possible, only and are assumed to remain unchanged in the medium run.

Next, we examine separately the dynamics of both the wage share of unskilled workers and technology gap. After that, we conduct the analysis of the dynamical system formed by both variables and then explore the resulting stability conditions.

*3.1 The wage share dynamics*

Let us assume that the time derivative of the wage share of unskilled workers is a positive function of the gap between the wage share desired by unskilled workers and the current wage share of unskilled workers, as follows:

where is the wage share desired by unskilled workers and is an adjustment parameter.

By equation (4.a), given that the mark-up rate is kept constant, the wage share desired by unskilled workers is directly related to relative labor productivity, , and inversely related to relative wages, , as follows:

where .

Now, assume that both and are affected by the level of technological capabilities of the economy:

where and . In (15.a), if labor productivity of skilled workers is more (less) responsive to technological progress than labor productivity of unskilled workers, than ; in (15.b), if the sensitivity of wages of skilled workers is greater (less) than the sensitivity of wages of unskilled workers to changes in the level of technological capabilities, then .

Substituting from (15.a) and (15.b) into (14), we have:

where and . For the sake of tractability and in line with the empirical evidence already mentioned, we will assume that . A positively signed in equation (16) implies that the adoption of new technologies disproportionally affects unskilled labor, since the increase in the wage gap outweighs the increase in the productivity differential; alternatively, a negatively signed illustrates a scenario in which the rise in the productivity differential is not accompanied by the wage gap in the process of technological catching-up, thus augmenting the wage share of the unskilled workers in detriment of the wage share of skilled workers for a given profit share. It is also assumed that is positive and sufficiently large to satisfy the following constraint: .

Substituting from equation (16) into (13), we have:

Next we examine the dynamics of the technological capabilities of the economy.

*3.2 The technology gap dynamics*

The dynamics of the technology gap , defined as the ratio of home country’s technological capabilities to foreign country’s technological capabilities, is determined by two variables, namely the rate of capital accumulation , in order to capture the Verdoorn effect[[9]](#footnote-9), and the level of the technology gap itself.

where are constants. Equation (18) shows that, for a given rate of capital accumulation of the foreign economy, a change in capital deepening in the domestic economy stimulates learning-by-doing, encourages R&D and increases the relative level of technological capabilities of the home country. Equation (18) is also in line with the vast empirical literature strongly suggesting that rising wages may stimulate labor-saving technological progress (e.g. Rowthorn, 1999; Storm and Naastepad, 2011; Vergeer and Kleinknecht, 2010-11), since an increase in the wage share of the unskilled workers boosts capital accumulation and so technical change. Lastly, it is also assumed that the rate of change of technical progress is a negative function of the inverted technology gap. ‘This happens because the higher the technology gap, the higher the opportunities for learning related to imitation, international technological spillovers and catching up’ (Cimoli and Porcile 2014, p. 217).

*3.3 The dynamical system*

Let us assume that the system formed by equations (17) and (18) in the *loci* and have at least one non-homogeneous equilibrium solution, , within the domain economically relevant, that is and . For simplicity, the analytical equilibrium solution of the system will not be formally presented here.

In the medium run equilibrium, the income distribution between skilled and unskilled labor is kept constant, which is reflected in the relationship between and within the *locus* . As a corollary, given a constant mark-up (and consequently a constant profit share), the income distribution between workers and capitalists also remains unchanged in equilibrium. Thus, in the *locus* , we obtain:

Since , equation (19) must necessarily satisfy two conditions: and .

Analogously, we also assume that the technology gap remains constant in the medium run. From equation (18), in equilibrium we must have . Thus, we linearize the resulting equation around the equilibrium solution , in order to obtain the following specification:

Now we focus the analysis on the local stability conditions of the equilibrium solution . From equations (17) and (18) we form a 2x2 non-linear dynamical system for the wage share of unskilled workers in income and technological gap. See below the Jacobian matrix of the system:

Let us analyze the parameters of the model. From equation (12), we know that and . Thus, it is worth remarking that the term is ambiguously signed.

The local stability condition of the system (21) around the equilibrium point requires a negative trace and a positive determinant of the coefficient matrix. More formally, if and , then the equilibrium solution is locally stable. Note that the stability of the system depends on the term . If , then we have and , thus implying that the system is unequivocally stable around the equilibrium point; if we have , then the solution of the dynamic system becomes more prone to instability. In economic terms, the solution of the dynamic system depends on three very intuitive variables: (i) the size of diminishing returns on technological catching-up (), in which a sufficiently larger generates a stable system; (ii) the size of the differential , which represents the impact of technological change on the rate of capital accumulation. If is sufficiently large, so that a rise in has a sizable impact on improving the non-price competitiveness of domestic goods and, consequently, the country’s net exports, the system is more likely unstable; and (iii) the sensitivity of the impact of capital accumulation on technological change (in which a higher increases the chance of an unstable dynamic system.

Henceforth it will be assumed for convenience that the diminishing returns of technological catching-up ( are sufficiently large, so that and the system is stable around the equilibrium point. Figure 1 below illustrates the stable dynamics (see the alternative scenarios in Appendices A.1 and A.2):

[FIGURE 1 ABOUT HERE]

It is noteworthy that the slope of the curve in equation (20) depends on the sign of the term . If , then the curve is upward sloping. Figure 1 shows the phase diagram with a stable equilibrium, represented by equilibrium point A. For instance, let us assume that a shock raises the income share of unskilled workers, so that it moves the economy to the right of equilibrium point A. In a first moment, a higher income share of unskilled workers will foment technological change (due to an increase in capital accumulation), which will then lead to a raise in the income share of skilled workers (as technological change disproportionally favors skilled workers). As this process continues, both technological change and the income share of unskilled workers start to fall, until the point where the technological gap has been largely reduced (*T* is too small) and the share of unskilled labors starts rising again. This process continues as the economy converges asymptotically towards the equilibrium.

What happens if this economy experiences a positive shock in the autonomous level of technological capabilities? From equation (18) such a shock is represented in terms of the model by an increase in .

[FIGURE 2 ABOUT HERE]

Figure 2 shows how a raise in shifts the isocline upwards. This shift leads the economy to a new equilibrium with higher technological gap and lower income share of unskilled workers. This shift has an ambiguous impact on capacity utilization: on one hand, a rising *T* has a positive impact on non-price competitiveness, thus increasing net exports, capacity utilization and accumulation. On the other hand, as the income share of unskilled workers is reduced, aggregate demand drops, thus leading to a fall on capacity utilization and accumulation. The net impact will depend on the magnitude of the opposing mechanisms.

Taking the linear approximation of equation (12) on the equilibrium point and rearranging the terms, we have:

By mapping out the set of iso-growth curves, each of which consisting of a constant deviation of from its equilibrium value , we obtain two possible scenarios:

[FIGURE 3.A ABOUT HERE]

[FIGURE 3.B ABOUT HERE]

In the case of an expansionary shock, represented by Figure 3.A, an increase in the level of technological capabilities spurs capital accumulation and output growth. This is due to the fact that the positive impact of technological change on the home country’s exports overcompensates the negative effect on aggregate consumption following a drop in the wage share of the unskilled workers, thus boosting capital accumulation. The case of a contractionary technological shock is represented in Figure 3.B. In this scenario waves of technological shocks may amplify income inequality and stagnate the economy.

Our next step is to understand how a policy mix can change these results, so that a technological shock becomes unambiguously positive.

*3.4 The case of a policy mix*

In the previous section we have shown that the negative effect on aggregate consumption following a raise in income inequality can outweigh the positive impact of technological change on capacity utilization, thus slowing down capital accumulation and growth (Figure 3.B). In this spirit, we advocate that technological policies should be accompanied by income transfer policies and public investment in higher education for the unprivileged in order to counterbalance the negative impact of knowledge-intensive technological progress in a stagnated economy.

Let us assume again a positive shock in the autonomous level of technological capabilities, represented by a rise in , which thus shifts the isocline upwards. Now assume that this shock is followed by an income transfer policy. This is represented by an increase in , which thus shifts the isocline upwards (see Figure 4.A). As presented above, a technological shock raises *T* and lowers . However, when an income transfer policy is put in place, the income share of unskilled workers increases, thereby leading to an increase in aggregate demand, capital accumulation and further technological change. The new equilibrium has an unambiguously positive impact on capacity utilization and capital accumulation.

[FIGURE 4.A ABOUT HERE]

Now let us assume a different type of policy. Suppose that the government decides to increase public investments in higher education. In this scenario, the replacement of unskilled workers by machines is reduced compared to the baseline scenario. In terms of the model, such a public policy is represented by a fall in the absolute value of By equation (19), a drop in rotates the isocline counterclockwise and shifts the intercept upwards (see Figure 4.B).

[FIGURE 4.B ABOUT HERE]

Comparing Figures 4.A and 4.B allows us to suggest that public investments in higher education may be more effective than income transfer policies to alleviate the unwanted effects of a contractionary wave of technological change and so promote a sustained economic recovery.

1. **Concluding remarks**

This article has developed a neo-Kaleckian formal model that accounts for the dynamical relationship between skilled-biased technological change and intra-working class income distribution. In the short-run equilibrium, the model allows us to conclude that: (i) a higher wage share of skilled workers relative to unskilled workers reduces capacity utilization and hence slows down capital accumulation; (ii) a more sophisticated, knowledge-intensive productive structure improves non-price competitiveness of the economy, thereby boosting net exports, capacity utilization and investment.

In the medium run analysis, these two forces interact and the net impact of technological change on capability utilization and capital accumulation can go either way. On the one hand, technological progress raises exports and boosts capital accumulation. On the other hand, technological change also raises inequality and so reduces aggregate consumption. Thus, the less responsive aggregate demand is to variations in the wage share of unskilled workers, the more likely it is that capacity utilization and capital accumulation will increase as a result of a positive technological shock.

In terms of policy, the framework proposed in the present work sheds further light on the relevance of income transfer and educational policies for the economy’s sustained growth strategy. Income transfer policies increase the income share of unskilled workers, which thus increase aggregate demand and capital accumulation. Additionally, educational policies diminish the impact of changes in production processes on the demand for unskilled labor. The model shows that, in this case, both technological change and the income share of unskilled workers increase when compared with the baseline scenario.

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**Appendix**

[FIGURE A.1 ABOUT HERE]

[FIGURE A.2 ABOUT HERE]

**FIGURES**

Fig. 1 – Stable scenario with upward slopping

A

Fig. 2 – Positive shock in the autonomous level of technological capabilities

Fig. 3.A – Expansionary technology shock

Fig. 3.B – Contractionary technology shock

Fig. 4.A – Income-transfer policy

Fig. 4.B – Investment in education

**APPENDIX**

A. 1 – Unstable scenario with downward slopping

A. 2 – Stable scenario with downward slopping

1. \* We are grateful to Gilberto Lima and Gabriel Porcile for useful comments and suggestions. The usual disclaimer applies. [↑](#footnote-ref-1)
2. Skott and Guy (2005, 2007) give an alternative explanation to the role of new technologies to earnings inequality, named Power-Biased Technological Change (PBTC). The authors argue that new information and communication technologies increase firm’s ability to monitoring labor in tasks that are less sophisticated, thus reducing the power of low-skilled workers. Within an efficiency wage framework, the authors show that PBTC (a rise in firm’s ability to monitoring) can account for a rise in the wage and employment differential between skilled and unskilled workers. [↑](#footnote-ref-2)
3. Blecker (1989) and Bhaduri and Marglin (1990) extend Dutt’s (1984) neo-Kaleckian model in a more general framework that allows us analyze both wage- and profit-led demand regimes. In their framework, if aggregate consumption is more (less) sensitive to a raise in the wage share than both investment and net exports combined, then we have a wage-led (profit-led) growth regime. [↑](#footnote-ref-3)
4. Some empirical evidence gives support to the idea that demand is more likely to be profit led in the short run and more likely to be wage led in the long run by showing that the impact of a rising wage share on aggregate demand is highly sensitive to lag lengths (Kiefer and Rada, 2015; Vargas Sánchez and Luna, 2014). [↑](#footnote-ref-4)
5. The paper by Tavani and Vasudevan (2014) is perhaps the closest in spirit to our work. The authors discuss the case of an economy with two-types of labor – workers and managers – and investigate the implications of a dominant managerial class for the dynamics of demand and distribution. However, while Tavani and Vasudevan (2014) focus on the top 1% of the income distribution, our focus is the SBTC and its impact on intra-working class income distribution in open developing economies. [↑](#footnote-ref-5)
6. A “canonical” neo-Kaleckian investment function would include the profit share in production, such that: , where is the profit share. However, as the focus of our paper is the impact of intra-working class income distribution on investment, we assume, for the sake of simplicity, that the profit share is constant and thus is equal to zero. [↑](#footnote-ref-6)
7. Carvalho and Rezai (2015) find empirical evidence for the US economy that the propensity to save increase from the bottom to the top quintile of wage earners. Therefore, redistribution from the top to the bottom quintile increases aggregate demand. [↑](#footnote-ref-7)
8. See Cimoli et al. 2016 for a summary of the discussion on non-price competitiveness. [↑](#footnote-ref-8)
9. The Verdoorn effect is the statistical relationship between the growth of labour productivity and manufacturing output; empirical evidence for the same relationship between these two variables seems to be very weak for the other sectors of the economy (McCombie and Thirlwall, 1994). The existence of a positive Verdoorn coefficient enables a country or a region to achieve a virtuous cycle of growth, as higher rates of growth in manufacturing increase learning, technical change and labor productivity. [↑](#footnote-ref-9)