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Does Imported Skill-Biased Technological Change Originate None, One or Many Kuznets Curves?

by

Gianluca Grimalda[†] and Marco Vivarelli[‡]

Abstract

We draw on a dynamical two-sector model and on a calibration exercise to study the impact of a skill-biased technological shock on the growth path and income distribution of a developing economy. The model builds on the theoretical framework developed by Silverberg and Verspagen (1995) and on the idea of localised technological change (Atkinson and Stiglitz, 1969) with sector-level increasing returns to scale. We find that a scenario of catching-up to the high-growth steady state is predictable for those economies starting off with a high enough endowment of skilled workforce. During the transition phase, if the skill upgrade process for the workforce is relatively slow, the typical inverse-U Kuznets pattern emerges for income inequality in the long run. Small scale Kuznets curves, driven by sectoral business cycles, may also be detected in the short run. Conversely, economies initially suffering from significant skill shortages remain trapped in a low-growth steady state. Although the long-term trend is one of decreasing inequality, small-scale Kuznets curves may be detected even in this case, which may cause problems of observational equivalence between the two scenarios for the policy-maker. The underlying factors of inequality, and the evolution of a more comprehensive measure of inequality than the one normally used, are also analysed.

JEL classification numbers: **O33, O41.**

Key words: Skill-biased technological change; inequality; Kuznets curve; catching-up.

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1. Introduction

'...Is the pattern of the older developed countries likely to be repeated in the sense that in the early phases of industrialization in the underdeveloped countries income inequalities will tend to widen before the levelling forces become strong enough first to stabilize and then reduce income inequalities?' (Kuznets, 1955, p.24).

In the last two decades, within-country income inequality (WCII) has shown different patterns around the world. Even though the 'average' country can be said to have experienced an upward trend during this period (Sala-i-Martin, 2002, Fig. 11), examples of increasing and decreasing trends can be found in both developed and developing countries. Since several countries have at the same time been affected by a process of increasing globalisation, intended as increased international trade and foreign direct investments, it has been natural for economists to ask whether a causal link between globalisation and income inequality exists. The focus of this paper is in particular on developing countries (DCs).

On the theoretical side, standard trade theory, based on the Stolper-Samuelson corollary of the Heckscher-Ohlin theorem, actually predicts that in developing countries, where abundant unskilled labour is cheap, one should observe trade driving the demand for the unskilled-labour-intensive goods, thus decreasing WCII. The main counter-argument to the Stolper Samuelson theorem is based on the skill-enhancing-trade hypothesis (Robbins, 2003) which points out that trade liberalisation in DCs implies importation of machinery from the North, leading to capital-deepening and (given capital-skill complementarities) to rising relative demand for skilled labour¹. That such a process of imported skill-biased technological change (ISBTC) has recently taken place in middle-income DCs has been convincingly proven by Berman and Machin (2000). On

¹ On the empirical side, some authors conclude that the opening process has nothing to do with increasing WCII (Edwards, 1997; Higgins and Williamson, 1999; Dollar and Kray, 2001), while others show a positive correlation in contrast with the Stolper-Samuelson prediction (Lundberg and Squire, 2001; Cornia and Kiiski, 2001; Ravallion, 2001).

the grounds of this literature, Vivarelli (2004) shows a significant impact of increasing import on the WCII, using a sample of 34 DCs who recently engaged in opening their economies to international trade.

This evidence opens the way to a reconsideration of the so-called Kuznets curve. Kuznets's seminal analysis refers to the long-term process of industrialisation and urbanisation that affects countries at their early stages of development. Kuznets's 'story' is that the shift of labour from the agricultural sector (where both per-capita income and within-sector inequality are low) towards the industrial/urban sector (which starts small, with higher per-capita income and a relatively higher degree of within-sector inequality), results in an inverted U-shaped curve relating economic growth to WCII (Kuznets, 1955: Table 1, p.13.). In what follows, we shall refer to this account as Kuznets I.

By focusing on developed countries, 'new' growth theorists have argued that a similar type of non-linear dynamics should also occur as a consequence of skill-biased technological change (SBTC) (see e.g. Galor and Tsiddon 1996; Aghion *et al.*, 1999). The argument runs as follows. The introduction of an SBTC triggers an increase in skilled labour demand and of the skill premium, thus determining an increase in inequality and originating the first segment of the Kuznets inverted-U curve. Then, widening wage-gaps induce the unskilled to invest more in the formation of human capital through education, learning and training. Hence, as workers upgrade their skill levels, the skilled labour supply increases, thus reducing the skill premium and inequality, and giving rise to the second segment of the Kuznets curve.

Although different accounts of the technological transition are consistent with this general idea, a Kuznets curve originates as a result of wage evolution and changes in the composition of the labour supply. Hence, these theories account for the recent rise of WCII in developed countries in terms of the upward part of the Kuznets curve, and predict an inequality-decreasing trend for the years to come. The reason is that a period of 15-20 years from the original SBTC is seemingly sufficient for the inequality-decreasing forces to counteract the initial inequality-

enhancing effect (Aghion *et al.*, 1999, p. 1655). Given the supposedly shorter time scale of the latter account with respect to Kuznets's original, and given the different unit of analysis – rich or middle-income countries vis-à-vis DCs – we shall refer to this latter account as Kuznets II.

On the empirical side, the Kuznets curve was commonly accepted in the 70s (see Ahluwalia, 1976), while more controversial results were found in the following years (see Anand and Kanbur, 1993; Li, Squire and Zou, 1998). However, more recent studies have given further support to the law (Barro, 2000; Reuveny and Li, 2003).

The purpose of this paper is to analyse the impact of an ISBTC on WCII investigating the extent to which the transfer of skill-biased technology to middle-income DCs can trigger a Kuznets II dynamics. This is achieved through a 'calibration' exercise, in which a dynamical two-sector model is applied to the case of DCs through calibrating values for its parameters and initial conditions on data relative to a sample of middle-income DCs. In particular, depending on the amount of skilled productive forces that the economy is endowed with at the time of the ISBTC, and on the initial productivity of the skilled intensive technology, different scenarios can be generated in terms of the effects of the technological diffusion on WCII and the growth rate of the country. This theoretical framework also enables us to take into account a number of factors affecting WCII in addition to those highlighted in the Kuznets I and II accounts, such as (a) the evolution of unemployment in both the skilled-intensive and the unskilled-intensive sector and (b) the dynamics of income distribution between capital and labour.

The main result of the analysis is that an evolution *a la* Kuznets of WCII appears indeed possible in the long run, but this only happens in those countries in which the supply of skilled labour is sufficiently high when the ISBTC takes place, so that the skill-intensive technology successfully diffuses within the economy. Moreover, even in this case, it is necessary that the upgrade process for the workforce be sufficiently slow in order for this result to obtain. On the other hand, the investigation also emphasises the possibility of failure in the diffusion of the advanced technology within the economy, in particular when skilled resources are initially in

short supply. In fact, this can easily be the typical situation of those DCs characterised by institutional constraints in their educational and training systems (including firms' inability to provide on-the-job training and to develop an adequate path for human capital upgrade). Here, a vicious cycle sets in of low investments in the high-tech sector and persisting skill shortages due to the lack of incentives for the workforce to upgrade their skills. This result is consistent with the technology-gap approach in emphasising the possibility of multiple steady states (see Fagerberg, 1994 for a review, and Fagerberg and Verspagen, 2002). As a result, the economy gets trapped in a low-growth development path due to technological lock-ins. In this case, depending on the initial relative productivity of the skill-intensive technology, either a path of relatively low inequality occurs, which leads to a scenario of substantial equality coupled with poverty, or income inequality increases in the short run and is later reabsorbed.

This latter scenario is particularly noteworthy, as it engenders a pattern resembling a Kuznets curve on a small scale. Diagrammatic and statistical analyses of the computer-generated data help show that such a short-run pattern is associated with sectoral business cycles, tensions in the labour market, and the dynamics of income distribution, all of which are triggered by the ISBTC, rather than the underlying forces of the Kuznets II account. As a result, the initial inequality-enhancing effect caused by the increase in the skill differential is here compensated by a decrease in skilled labour *demand* rather than through adjustments in skilled labour supply. The fact that such short-term Kuznets curves driven by the business cycle also occur in the scenario of technological catching-up alongside the long-term one may be a cause of concern for the policy-maker. The reason is that, since these two scenarios are observationally equivalent in the short run, it would be wrong to infer from the observation of rising inequality that an advanced technology is diffusing among the economy, as a superficial reliance on the Kuznets II account may suggest. In fact, the rising pattern of inequality may be due to a short-term effect of the business cycle in the presence of relevant skill shortages, even when the skill-intensive technology fails to take off in the economy in the long run.

Overall, the scenarios that are generated by this investigation are seen as possible explanatory models of the different patterns of income inequality that are being observed in DCs. In particular, the latter scenario may provide a plausible interpretative account for the recent WCII dynamics in those middle-income globalizing DCs which have opened to international trade but whose process of catching-up is stagnating (examples are most Latin-American countries, some Middle-East and North-African countries and most of previous Soviet Republics).

The theoretical underpinnings of the model and the analysis of its steady states are presented in Section 2. The theoretical framework is based on Silverberg and Verspagen (1995) and it consists of a dynamical two-sector model characterised by increasing returns to scale at the sectoral level, which generates unbalanced growth and multiple steady states. In section 3 the initial conditions of the perturbed system are calibrated on real data from middle-income DCs starting with a relatively high percentage of skilled agents. In this section we show that the Kuznets II account can be replicated with respect to middle-income countries engaged in a globalisation process. Section 4 studies the WCII dynamics in the case of substantial skill shortages leading to a ‘regressive’ dynamics of failure in technological catching-up and the scenario characterised by a short-term spurt in inequality is analysed. Section 5 concludes.

2. The Theoretical Framework

2.1 The Model²

There exist two key *sectors* in the economy; the ‘modern’ one employs a skilled-labour intensive technology, whereas the ‘traditional’ sector makes use of an unskilled-intensive technology. For simplicity, the modern (traditional) sector solely employs skilled (unskilled) labour. As illustrated in section 2.3, we shall characterise these two sectors as the high-tech and the low-tech sectors within manufacturing in middle-income DCs. Moreover, each technology is

² An extensive discussion of the model can be found in Grimalda (2002).

uniquely associated with a technique of production, so that each sector can be represented by a Leontief production function:

$$Q_i = \min\left\{a_i L_i, \frac{K_i}{c}\right\} \quad i = 1, 2 \quad (1)$$

L_i and K_i (L_2 and K_2) are the employment of skilled (unskilled) labour and capital in the skill-intensive (unskilled-intensive) technology. c is the constant capital/output coefficient, whereas a_i is labour productivity in sector i .

Each sector of the economy follows a sector-specific “learning curve” (see e.g. Krugman, 1987), e.g. because technological knowledge has some sector-specific characteristics that cannot be transferred across the sectors of the economy (see e.g. Dosi, 1988). This brings about dynamic increasing returns to scale at the sectoral level, and localised technical change (Atkinson and Stiglitz, 1969). In particular, Equation 2 assumes that sectoral productivity growth rates are positively related with the share of economic activity taking place within each sector:

$$\frac{\dot{a}_i}{a_i} = g_i \kappa_i \quad (2)$$

κ_i denotes the share of capital invested in sector i . g_i are parameters characterising the productivity gains in the sectors of the economy. A stylised fact is that the skill-intensive technology should, *ceteris paribus*, bring about higher productivity growth rates. This is in fact confirmed – on average – in our dataset for DCs (see conditions 11 and 13 below). Thereby, we set $g_1 > g_2$.

As for the price setting rules, the country is assumed to sell its product on the world market, thus the demand for its output is perfectly elastic, as any amount of output that is produced can be absorbed by the world market at the given price. Hence, commodity prices are assumed constant throughout the analysis. Equation (3) accounts instead for the wages dynamics. Here, we assume that labour markets do not clear instantaneously, but that wages evolve in accordance with the imbalances between demand and supply:

$$\frac{\dot{y}_i}{y_i} = \begin{cases} \gamma(x_i - L_i^S) + (\eta_i - 1)\kappa_i g_i & \text{if } y_i < 1 \\ \min\{0, \gamma(x_i - L_i^S) + (\eta_i - 1)\kappa_i g_i\} & \text{if } y_i = 1 \end{cases} \quad (3)$$

y_i is the unit cost of labour for sector i . That is, $y_i \equiv \frac{w_i}{a_i}$, where w_i are sectoral wages. The growth rate of y_i is made up of two components. The first is given by the excess of labour demand - denoted by x_i - over supply - denoted by L_i^S . In particular, sectoral labour demand is defined as $x_i = \frac{K_i}{a_i c}$. The speed at which labour market imbalances affect wages is measured by the parameter γ . The second component is associated with a sector-specific redistributive mechanism independent of market forces, which assigns a ‘bonus’ to wages equal to a portion η_i of sectoral productivity gains.³ The second line of (3) describes the wage dynamics when profits just equal zero.

Equation (4) characterizes the rule of motion for capital share invested in the skill-intensive sector. It is grounded on the idea that agents are boundedly rational because of cognitive and informational limitations on the environment in which they operate (Simon, 1955; Nelson and Winter, 1982). Therefore, at each instant of time only a fraction of agents can adjust to the currently optimal action, and the aggregate behaviour that obtains is modelled according to a version of a *replicator* dynamics.

$$\frac{\dot{\kappa}_1}{\kappa_1} = \begin{cases} \frac{(1+\alpha)}{c} (1-\kappa_1) [u_1(1-y_1)(1-\tau_1(\kappa_1)) - u_2(1-y_2)] & \text{if } u_1(1-y_1)(1-v_1(\kappa_1)) > u_2(1-y_2) \\ -\frac{(1+\alpha)}{c} (1-\kappa_1) [u_2(1-y_2)(1-\tau_2(\kappa_1)) - u_1(1-y_1)] & \text{if } u_2(1-y_2)(1-v_2(\kappa_1)) > u_1(1-y_1) \\ \frac{(1+\alpha)}{c} (1-\kappa_1) [u_1(1-y_1) - u_2(1-y_2)] & \text{otherwise} \end{cases} \quad (4)$$

This equation may be construed as made up of two components; the former is based on the idea that capital-owners reinvest all of their profits in the sector where they are operating,

³ Such a component can best be seen as the effect of bargaining over income distribution. In particular, the higher η_i the stronger the bargaining power for workers and thus their income share. This parameter also determines the steady state level of structural unemployment for the economy.

whereas workers consume all of their income⁴. This component would make sector investment equal to the sectoral profit rate. In addition to such a ‘normal’ sectoral capital accumulation rate, there is another component that is caused by the reallocation of capital across sectors operated by entrepreneurs in search of higher profits⁵. α is an exogenous parameter that measures both the ‘structural’ component in the speed with which information is diffused among entrepreneurs and the technical constraints that alter the speed at which intersectoral switches can occur. Furthermore, the possibility of firms being rationed because of labour shortages is considered by means of the variable u_i , which represents the degree of capacity utilisation of capital in sector i .

An additional aspect is taken into account in sectoral capital accumulation, that is, an entrepreneur’s switch to the alternative sector is conditional on the payment of an adjustment cost, which is expressed in (4) by the functions $v_1(k)$ for the upgrade and $v_2(k)$ for the downgrade⁶ costs respectively⁷.

⁴ This is an adaptation to a multi-sector economy of the behavioural rule typical of Kaldorian models (Kaldor, 1957). Nothing substantial would change in the model if workers’ propensity to consume and entrepreneurs’ propensity to invest was constant, but less than one.

⁵ The stylised story underlying this equation is that a fraction of entrepreneurs randomly acquire some piece of information at each instant of time regarding the profit rate earned in the alternative sector. Were the profit rate earned in the other sector higher than the currently one, they may decide to switch sector of production. However, due to a variety of ‘retardation factors’ associated with agents’ bounded rationality (Soete and Turner, 1984: 617), such an adjustment process is sluggish. As a result, only a fraction of agents is able to migrate to the more profitable sector at each instant of time. In the model we adopt, the portion of agents switching to the alternative sector depends on the magnitude of the difference in the profit rates, the idea being that a higher differential in sectoral profit rate is likely to spur a faster diffusion of the ‘good news’ of the existence of a more profitable technology among agents.

⁶ Given the characterisation of technique 1 as skilled-labour intensive, we shall define *upgrading* the migration from unskilled-intensive technology to skilled-intensive, and *downgrading* the movement in the opposite direction. Note that when we refer to an agent as ‘skilled’ we do not refer to the ease with which she can upgrade, but only to whether she is currently employed in the skilled-intensive sector.

⁷ We assume that such costs vary depending on the entrepreneur’s degree of specialisation in a particular technique, so that the higher the specialisation, the lower the cost of taking up the related technology. Such a degree of specialisation is thought of as an immutable characteristic of the firm, acquired prior to the undertaking of economic activities, and it solely affects adjustment costs, rather than productivity. Moreover, specialisation is technique-

Finally, equation (5) describes the rule of motion for skilled labour, which is denoted by s :

$$\dot{s} = \begin{cases} \beta s(1-s) \left[\left(\frac{L_1}{s} \right) w_1(1-\mu_1(s)) - \left(\frac{L_2}{1-s} \right) w_2 \right] & \text{if } \left(\frac{L_1}{s} \right) w_1(1-\mu_1(s)) > \left(\frac{L_2}{1-s} \right) w_2 \\ -\beta s(1-s) \left[\left(\frac{L_2}{1-s} \right) w_2(1-\mu_2(s)) - \left(\frac{L_1}{s} \right) w_1 \right] & \text{if } \left(\frac{L_2}{1-s} \right) w_2(1-\mu_2(s)) > \left(\frac{L_1}{s} \right) w_1(s) \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

It is analogous to equation (4) in that workers' movements across sectors are triggered by the comparison of the expected wage earned in the two alternative sectors, net of the payment of an adjustment cost that decreases in their level of sector-specific specialisation. Costs are represented by the functions $\mu_1(s)$ and $\mu_2(s)$, which have the same interpretation as the functions $v_1(k)$ and $v_2(k)$ illustrated above. Similarly, β , like α , measures the information diffusion rate among workers and the speed of cross-sectoral mobility.

If we abstract away from the between-sector linkages, then x_i and y_i follow a Lotka-Volterra model, where the dynamics of income distribution between capital-owners and workers causes these variables to follow a cyclical behaviour (Goodwin, 1967). In fact, on this account, if the system finds itself in a phase of high investments, the consequent excess of labour demand will drive wages up, thus reducing the rate of profit and investment. In turn, this will decrease the level of production and employment, so that wages drop and this triggers a new phase of increase in investments. However, this basic mechanism is in the present model affected by cross-sector movements of capital and labour.

specific, so the higher the specialisation in a particular technique, the lower the specialisation in the alternative one. This enables an ordering of entrepreneurs on the $[0,1]$ interval, depending on their higher or lower degree of specialisation in technique 1 *vis-à-vis* technique 2. In particular, the higher a firm's specialisation in technique 1, and the lower its specialisation in technique 2, the closer it will lie to the left hand-side of the interval, and *vice versa*. Finally, the choice of the parameters related to these functions makes the upgrade costs generally higher than the downgrade costs. The functional form that has been used in the simulations is as follows: $v_1(\kappa) = \kappa^{\tau_1}$ and $v_2(\kappa) = (1-\kappa)^{\tau_2}$. τ_1 and τ_2 are parameters determining the magnitude of the upgrade costs: the higher the parameter, the higher the cost for each member of the population to improve their skill.

2.2 The Steady States of the Model

Given the presence of increasing returns to scale at the sectoral level, the model is characterised by multiple steady states, which differ in relation to the sectoral specialisation the economy undertakes and, consequently, to their growth rates, as convergence to the skilled-intensive technology guarantees higher growth rates. Convergence is determined by the structural conditions of the economy, such as the size of the adjustment costs sustained by workers and entrepreneurs in order to ‘migrate’ to the alternative sector of the economy, and by the dimension of skilled productive forces at the time of the ISBTC shock. In particular, both these aspects highlight the relevance of an economy’s absorptive capacity of advanced technologies as a key factor for catching-up (see Lall, 2004), and the scenarios studied in our investigation show that such capacities are not necessarily created through market mechanisms, at least in the presence of particularly adverse initial conditions.

The steady states of the system can be divided into three categories: convergence towards a high-growth equilibrium, convergence towards a slow-growth equilibrium, and a balanced growth path in which both sectors of the economy coexist. By *convergence* we mean the process that leads asymptotically to the complete allocation of capital and labour to one of the two sectors. That is, convergence is equivalent to *specialisation* in the production of one of the two commodities on the international scene.

The steady states implying sectoral convergence are symmetric and are reported below:

$$\left\{ \kappa_1 = 1 \quad y_1 = 1 - c g_1 \quad x_1 = 1 - \frac{(\eta_1 - 1)}{\gamma} g_1 \quad y_2 = \text{undetermined} \quad x_2 = 0 \quad s = 1 \right\} \quad (6)$$

$$\left\{ \kappa_1 = 0 \quad y_2 = 1 - c g_2 \quad x_2 = 1 - \frac{(\eta_2 - 1)}{\gamma} g_2 \quad y_1 = \text{undetermined} \quad x_1 = 0 \quad s = 0 \right\} \quad (7)$$

(6) implies convergence to the skilled-intensive sector of the economy, thus it ensures higher growth rates than (7), which is instead characterised by specialisation in the unskilled-intensive

sector.⁸ There exists structural unemployment in the steady state, which is a percentage $(\eta_i - 1)/\gamma$, $i = 1, 2$ of the workforce⁹. The local stability of the first two types of steady state cannot be assessed on purely analytical terms¹⁰. Still, the extensive simulation analysis that has been conducted shows that these are stable attractors of the system for a feasible constellation of parameters.

The balanced growth path solution, instead, depicts a situation in which the two sectors coexist and grow at the same rate, as productivity is the same.

$$\left\{ \begin{array}{l} \kappa_1 = \frac{g_2}{g_1 + g_2} \quad y_1 = \frac{g_2 + g_1(1 - cg_2)}{g_1 + g_2} \quad x_1 = s - \frac{(\eta_1 - 1)}{\gamma} g_1 g_2 \\ y_2 = \frac{g_2 + g_1(1 - cg_2)}{g_1 + g_2} \quad x_2 = 1 - s - \frac{(\eta_2 - 1)}{\gamma} g_1 g_2 \end{array} \right\} \quad (8)$$

Due to the property of cumulativeness of technological change and sector-specific increasing returns to scale (see section 2.1), this solution can be immediately ruled out as unstable.

2.3 Modelling the Impact of an ISBTC on a Low-growth Steady State

As discussed in the introduction, we model globalisation as a way to implement SBTC in a previously technologically backward country. SBTC is introduced directly through FDI,

⁸ Both steady states hold under the condition that η_1 and η_2 be greater than 1. A steady state for the case $\eta_i < 1$ can also be found, though it is now capital rather than labour to be rationed.

⁹ One can thus note that a greater speed of adjustment in the labour market, as measured by coefficient γ , helps reduce the level of unemployment, which at the limit for γ converging to infinity is equal to zero. Hence, it is the introduction of non-instantaneous market clearing within the model what brings about structural unemployment. α and β do not instead affect the steady states in this specification. However, were labour supply fixed in each sector (see Grimalda, 2002), then α would determine the steady state values for y_1 and y_2 , in such a way that α approaching infinity would cause the sectoral profit rates to be equal. Since this corresponds to the situation of full information and cognitive ability of the agents (see section 2.1), the usual neoclassical condition of cross-sector equality in profit rates may be viewed as a limit case of this version of the model. Although the value for y_i , $i=1,2$, turns out to be undetermined in (6) and (7), the subsequent numerical analysis clearly shows that such a variable tends to the value of 1, i.e. to the situation of zero profits in the sector that remains residual in the economy.

¹⁰ This is due to the presence of some purely imaginary eigenvalues making the system locally non-hyperbolic (Guckenheimer and Holmes, 1990). For an extensive discussion of the dynamical properties of the system, see Grimalda (2002).

multinational plants and importation of more advanced capital goods, and indirectly through exposure to international competitiveness, so that more commodities become tradeable and domestic firms are induced to update their own technologies.

Despite the basic setting of the model being devised for a closed economy, we can investigate the impact of globalisation by means of a theoretical exercise, which consists in studying the evolution of the system after a low-growth steady state – supposedly a realistic representation for a DC lagging behind in the technological ladder - is perturbed as an effect of an ISBTC. In other words, we suppose that the economy shifts from the low-growth steady state to a position corresponding to the introduction of an SBTC into the economy. The extent of this shift is derived from real data, so as to reflect the actual weight of advanced technologies in a sample of middle-income countries during the ‘80s and ‘90s. The evolution of the system from the new starting position is then analysed, and in particular we focus on whether the country can successfully catch up and converge towards the high-growth steady state, and on whether a Kuznets type of dynamics can be triggered along the adjustment path.

As for the ‘calibration’ exercise of determining the magnitude of the ISBTC shock and the structural parameters of the economic system, we focus on the manufacturing sector and draw on the classification offered by the OECD Structural Analysis (STAN) database that divides the whole manufacturing sector into one group of high-tech and one of low-tech industries. We then compute population-weighted averages during the 80s and 90s for a group of middle-high income and one of middle-low income countries for the relevant variables of the model (data available upon request¹¹), which will underpin the scenarios of section 3 and 4 respectively.

Relying on this calibration, the evolution of WCII is studied by applying the Gini index to some relevant categories of income. A first measure is built in accordance with the Kuznets I and II accounts, which only consider the dynamics internal to *labour* income distribution. Since in our

¹¹ The classification of a country as middle-high or middle-low has been drawn from the UNU/WIDER-UNDP World Income Inequality Database (WIID), Version 1.0, 2000.

model there are two such categories, that is, skilled and unskilled labour, and a third of unemployed workers, the relevant cumulative population distribution and their related income is the following:

$$\begin{cases} 1-(L_1+L_2) & 0 \\ L_1 & w_1 \\ L_2 & w_2 \end{cases} \quad (9)$$

We call the resulting inequality measure the *restricted* Gini index (RGI)¹².

A second index of inequality can be computed by considering capital income as well as labour income. We shall refer to this as the *comprehensive* Gini index (CGI). The categories of income that are considered are now as follows:

$$\begin{cases} 1+n-[L_1+L_2+n(u_1\kappa_1+u_2(1-\kappa_1))] & 0 \\ L_1 & w_1 \\ L_2 & w_2 \\ nu_1\kappa_1 & r_1K \\ nu_2(1-\kappa_1) & r_2K \end{cases} \quad (10)$$

n is here the ratio between the capital-owners population and that of employees, so that the total population has a size of $1+n$ ¹³. The first category is now given by the sum of workers and entrepreneurs who are unemployed; the second and the third categories are occupied skilled and unskilled workers as in the RGI. The fourth and fifth categories are entrepreneurs active in the high-tech and low-tech sectors respectively, whose income is given by the relative interest rate multiplied by the aggregate level of capital. Since there is an additional factor of dispersion in CGI with respect to RGI, the inequality measured by the former will be higher than the latter.

¹² An important *caveat* is that our index only takes into account *between-group* inequality, whereas it neglects *within-group* inequality, as all of the agents belonging to each group are assumed to earn the same income. This obviously leads to a substantial under-estimation of inequality in absolute terms in our model. Nevertheless, we still believe that the main results of our analysis are not affected by this aspect, especially because it is not *a-priori* clear whether there exist significant differences in within-group inequality across the two groups.

¹³ Note that a characteristic of the model is that movements between the two populations of workers and capital-owners are not allowed. Observations of the relative size of employers vis-à-vis employees for developing countries (see e.g. KILM 2001 database, International Labour Office, Geneva) appear to imply a value for n as being below 5%, so we set $n=4\%$ in the simulations.

3. Evolution of Income Distribution as a Result of a ‘Progressive’ Technological Catching-up with Skill-upgrading

We first conduct a simulation where data are drawn from the sample of middle-high income countries. Parameters have been assigned the following values on the basis of theoretical considerations and real data¹⁴

$$\{g_1 = 3.955\% ; g_2 = 1.503\% ; U=7.499\% ; c=8.428 ; \gamma=2.5 ; \eta_1 = 5.470 ; \quad (11)$$

$$\eta_2 = 13.473 ; \alpha=1 ; \beta = 1 ; \lambda_1 = 0.5 ; \lambda_2 = 10 ; \tau_1 = 3 ; \tau_2 = 10 \}$$

Note that the high-tech sector productivity growth outstrips low-tech productivity by 2.45%.

As for the choice of the system’s initial conditions, as argued in the previous section, we suppose the economic system is located in the slow-growth steady state (7) before the ISBTC shock. Drawing on the population-weighted averages for the sub-sample of middle-high income countries (see Grimalda and Vivarelli (2004) – indicated as GV in what follows – Appendix, Table 1), these are the initial conditions for the endogenous variables of the system¹⁵:

¹⁴ In particular, values for the sectoral productivity growth rates g_1 and g_2 are drawn directly from the data. c , i.e. the inverse of capital productivity, has been assigned a value such that the implied capital income share is one third of total income in the high growth steady state. This is, in fact, the value generally used in growth accounting exercises to estimate capital income share (see e.g. Mankiw *et al.*, 1992: 410). This implies a capital income share of roughly 17% for the low-growth steady state, which accords with the idea that DCs have a lower capital income share than developed ones. γ has been assigned a value of 2.5, so that the business cycle has a length of 10 years in the basic single-sector version of the model (see section 2.1). The values of η_i have been determined in such a way that the level of average unemployment is equal to 7.499% in both sectors, which is the average value found in the data. α and β have been assigned the same value, which is taken from Soete and Turner (1984). Admittedly, it appears more problematic finding an empirical counterpart for the pairs of λ and τ (see footnote 7). The values chosen imply that upgrade costs are *ceteris paribus* greater than downgrade costs, as $\tau_1 > \tau_2$ and $\lambda_1 > \lambda_2$, and that upgrading costs for workers are higher than those for firms - for instance because some of these firms are multinational companies with a higher level of expertise in adapting to new technical paradigms than the local workforce.

¹⁵ In particular, we normalise a_2 to 1, and directly substitute the values of the wage ratio into the steady state to obtain the initial condition for y_2 . We then determine the value for y_1 in accordance with the productivity differential and skill premium of high-tech with respect to low-tech sectors that result from the data. These imply in particular a productivity advantage and a skill ratio for the high-tech sector of comparable size: 46% for the former and 47% for the latter. The starting value for skilled labour demand x_i and supply s has been drawn from the average of

$$\{a_1 = 1.466; a_2 = 1; \kappa = 0.3982, y_2 = 0.8733, x_2 = 0.6373, \\ y_1 = 0.8805, x_1 = 0.2877, s = 0.311\} \quad (12)$$

Note that κ replaces κ_1 hereafter.

The long-run outcome of this scenario is the specialisation of the economy in the high-tech sector (Figure 1). During the transition, a pattern resembling a Kuznets dynamics originates for both RGI and CGI (Figure 2 and 3). They reach a peak after 100 years, and then converge to their new steady state level, which is given by (6). Since this implies a higher capital income share than (7), income inequality measured by CGI shifts to a greater value in the new steady state¹⁶.

Diagrammatic and statistical analyses confirm that the usual mechanism underlying the Kuznets II account is at work here. In fact, there exist a number of explanatory factors for income inequality in the model. As far as RGI is concerned, inequality can be affected by (a) the wage differential; (b) skilled labour unemployment and (c) unskilled labour unemployment; (d) the proportion of skilled labour in the total. An additional factor is relevant in the determination of CGI, that is, (e) the distribution of income between labour and capital (due to space limitations, plots are not reported here but they are available from the authors on request, see also GV for a more extended analysis).

employment rates in the high-tech sector, which is approximately 31% of the workforce. Finally, we assume that both labour markets start off from a situation of unemployment of the same magnitude as that in the steady state. (8) is characterised by a position of ‘advantage’ for the skill-biased technology, in the sense that the labour productivity for skill-intensive technology is greater than for the other technology, but it also has a higher ‘potential’ for growth, as g_1 is larger than g_2 . However, skilled labour wages are also higher by an amount that slightly exceeds the productivity advantage, so that firms are initially almost indifferent between the two technologies in terms of profit rates, as y_1 is almost equal to y_2 .

¹⁶ More precisely, RGI is equal to 0.072 in both steady states, as the only source of inequality is here given by the ratio of unemployed workers to the total workforce, and this is by assumption the same in the two steady states. Instead, CGI increases from 0.151 in the low-growth steady state to 0.343 in the high-growth one due to the higher capital income share associated with the high-growth steady state. Note that the initial values for both the RGI and the CGI are actually higher than the values associated with the initial steady state. This is of course due to the fact that the initial conditions for the simulation exercise differs from the initial steady state by the amount of disturbance triggered by the ISBTC.

We split the analysis into three sub-periods. In the first 66 years, the proportion of skilled workers remains flat, as adjustment costs are too high and the wage differential still too low to make migration profitable for workers, thus this factor cannot influence inequality. Statistical analysis reveals that wage differential and labour income share are the most important factors in explaining RGI and CGI respectively, whereas unskilled labour unemployment has some influence on RGI (see Appendix, Table1, column (a)). In the successive period, from year 66 to years 106-120 (RGI reaches its peak earlier than CGI), two additional factors cause the upward trend of income inequality to be more pronounced than before and to lose its cyclical pattern: firstly, the start of workforce migration from the unskilled to the skilled sector (see Figure 1) - due to the enlargement of the ‘rich’ side of the population - has a *positive* effect on inequality. This is the case at least when the richer proportion of the population is relatively small¹⁷. Moreover, such a movement has the effect of enlarging skilled labour unemployment, thus making this variable now statistically significant; secondly, the substantial fall in the labour income share increases the inequality measured by CGI even further. All these factors appear statistically significant and add to the skill differential as explanatory factors for WCII in this period (Appendix, Table 1: columns (b), (c), (g), (h), (i)).

¹⁷ The migration of the workforce towards the skilled sectors has, in fact, two contrasting effects on the Gini index. On the one hand, there is a *scale* effect, whereby the proportion of poor individuals in the population decreases. On the other hand, there is a *relative poverty* effect, which implies that the labour share of the poor shrinks. The scale effect has a negative impact on inequality, whereas the relative poverty effect increases inequality: This can be clearly shown if we concentrate on the Gini index and assess the impact of a change in the fraction of the poor on the distribution of labour income, leaving the skill wage differential constant. It can be shown that the following formula holds: $\frac{dRGI}{dL_2} = \frac{1}{2} \left(1 - \frac{d\sigma}{dL_2} \right)$ where σ is the labour share of unskilled labour, and its derivative with respect to L_2 is

always positive. Hence, the two terms within brackets represent the scale and the relative poverty effects respectively. If we take unemployment to be constant, so that a decrease in L_2 implies a one-to-one increase in L_1 , which of the two effects prevails depends on the magnitude of L_2 . More precisely, the derivative of RGI is positive for values of L_2 less than some threshold level. Hence, when the proportion of unskilled labour is large, as is the case initially, the relative poverty effect dominates the scale effect, and thus inequality tends to grow. The opposite occurs as L_2 exceeds such a threshold value, which occurs after period 100 in this scenario.

As approximately half of the workforce has migrated to the skilled labour sector, the Kuznets curve starts its reversal. Since the wage differential is still rising, and this has an unambiguous positive effect on inequality, the inequality-decreasing effect of the other factors must offset the impact of the skill differential. In particular, the scale effect due to the continuous shift of workers to the ‘rich’ side of the income distribution now has the result of mitigating inequality (see footnote 17). In fact, skilled labour unemployment, the supply of skilled workers, and labour income share, all turn out to be statistically significant, unlike the wage differential and unskilled labour unemployment (see Appendix, Table 1: column (d), (e), (l), (m), (n))¹⁸.

Another characteristic of the model is that during the initial period in which adjustments in the workforce have yet to take place, several ‘short-term-Kuznets cycles occur, each of the approximate duration of 10 to 13 years (Figures 2 and 3). These will be investigated in section 4.

In order to better appreciate the relevance of the magnitude of the adjustment costs for the outcome of the simulation, we have run some simulations with lower adjustment costs for both workers and capital-owners¹⁹. This causes faster migration of both capital and labour towards the skilled-intensive sector, and in particular there is no initial delay in the migration of the workforce towards the skill-intensive sector. As a result, the evolution of income inequality is entirely different from before, following a decreasing trend that progressively converges towards its steady state value (see Figure 4). What causes the steep drop in RGI in the first years is the fact that the migration of the workforce towards the skill-intensive sector is initially so rapid that the skilled wage differential actually decreases in the early stages of this simulation. Afterwards, fast migration towards the skill-intensive sector offsets the rise in the wage differential. Therefore, the inverse-U shaped pattern observed in Figures 2 and 3 is by no means a necessary feature of

¹⁸ In this simulation, the whole cycle takes as long as 150-200 years to complete. However, it has to be said that the length of the cycle crucially hinges upon the value of the adjustment costs λ_1 , λ_2 and τ_1 , τ_2 . According to the simulations conducted, the shortest time it can take to reach a peak in the Kuznets curve in this model– which obviously occurs in the complete absence of any adjustment cost – is 27 years.

¹⁹ In particular, the adjustment cost parameters have been set equal to $\lambda_1 = \lambda_2 = \tau_1 = \tau_2 = 10$ in this second scenario.

income inequality along the transition path towards the high-growth steady state, but crucially hinges upon the workforce’s rapidity in skill upgrading, which in turn depends on the magnitude of the adjustment costs.

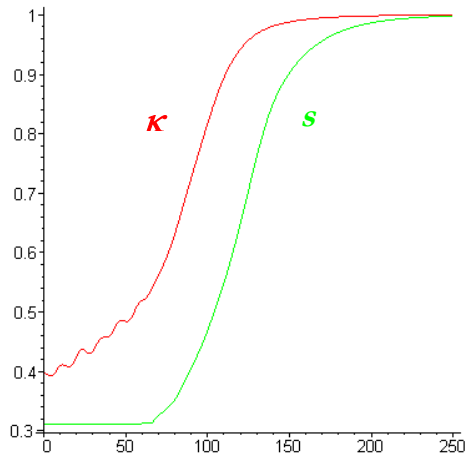


Figure 1: Evolution of skill-intensive capital share and skilled labour supply share (first scenario)

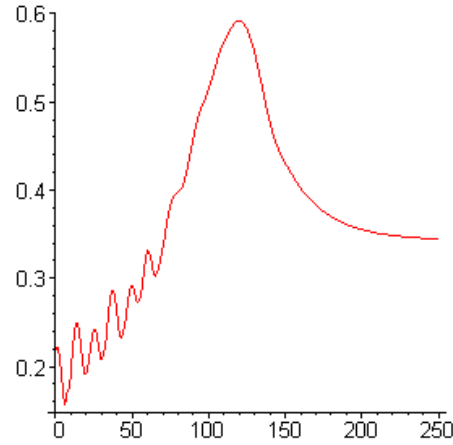


Figure 3: Evolution of CGI (first scenario)

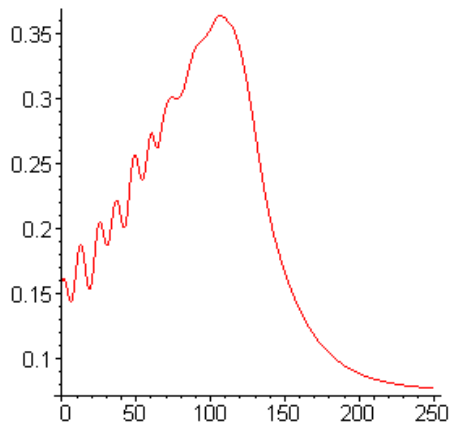


Figure 2: Evolution of RGI (first scenario)

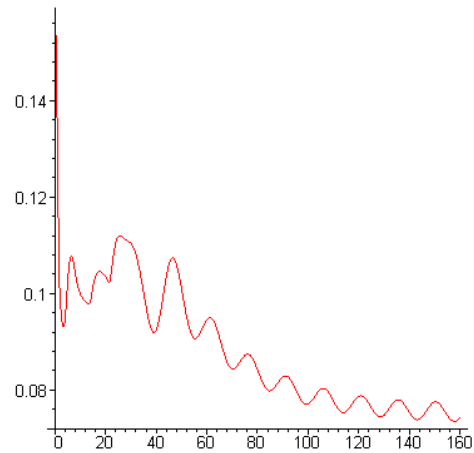


Figure 4: Evolution of RGI (second scenario)

4. Evolution of Income Distribution as a Result of a ‘Regressive’ Technological Lock-in without Skill Upgrading

In GV we analyse a scenario where the initial conditions and the relevant parameters are entirely derived from data relative to the sub-sample of middle-low-income countries. The most prominent characteristics of this scenario are that the economy remains trapped in the

low-growth steady state, and that no long-run Kuznets curve takes place. In fact, the impact of the ISBTC on income inequality is negative in the short run for both indexes, thus giving rise to a scenario that can be seen as carrying about both poverty and equality (GV: 22-25).

In this section we instead present a scenario that obtains upon a slight increase in the productivity premium with respect to this case²⁰, so that the following parameters and initial conditions obtain:

$$\{g_1 = 4.362\% ; g_2 = 2.145\% ; U = 7.658\% ; \alpha = 1 ; c = 7.642 ; \gamma = 2.5 ; \beta = 1 ; \quad (13)$$

$$\eta_1 = 5.389 ; \eta_2 = 9.925 \lambda_1 = 0.5 ; \lambda_2 = 10 ; \tau_1 = 3 ; \tau_2 = 10 \}$$

$$\{a_1(0) = 1.698 ; a_2(0) = 1 ; \kappa(0) = 0.316, y_2(0) = 0.836, x_2(0) = 0.726, \quad (14)$$

$$y_1(0) = 0.733, x_1(0) = 0.198, s(0) = 0.214\}$$

It is apparent that the differences in productivity growth rates and unemployment rates with respect to (11) are rather marginal. What instead proves to be significantly different is the proportion of skilled workers: this is now substantially smaller than the middle-high income country case, as it only amounts to 21% as opposed to the 31% of the previous case.

As Figure 5 shows, the long-run outcome is the specialisation in the low-tech sector and the failure in catching-up. The technological lock-in is ultimately determined by the structural conditions of the economy, and in particular by both the initial shortage of skilled labour and entrepreneurs and the presence of relevant adjustment costs in skill upgrading, which are the consequences of those institutional constraints in the education and training systems which can likely be found in many middle-low income developing countries.

The mechanism whereby such adverse structural conditions hinder catching-up is as follows. Given the presence of increasing returns to scale at the sectoral level, the persistently higher concentration of firms in the low-tech sector brings about in the long run higher

²⁰ More precisely, the productivity premium for the skill-intensive technology has been set equal to 62% rather than 41%, implying a 20% further increase with respect to the average of our data. That such a change leads to a realistic scenario is proven by the fact that a productivity differential at least as wide as 62% is the case for Indonesia, Morocco and Guatemala in our sample of middle-low income countries.

productivity growth rates, so that the economy eventually specialises in the low-tech sector. On the other hand, the presence of relatively high adjustment costs initially prevents workers from transferring to the high-tech sector. Such an incentive does not improve over time, because the lower concentration of firms in the high-tech sectors causes the wage differential to decrease over time (GV: Fig. 12). Consequently, the proportion of workers employed in the skilled sector initially remains constant and then decreases when the skill differential has actually turned in favour of the unskilled wage. In other words, the lack of a sufficient critical mass of skills, both in the workforce and in firms, gives rise to a vicious circle of decreasing investments in the high-tech sector, decreasing demand for skilled labour and decreasing productivity growth rates. This produces the characteristic snowballing effect leading to technological lock-in towards the backward technology.

However, this is only the picture that emerges in the long run. Looking more closely at the short-medium term, one can note that the high-tech technology shows a remarkable ‘resilience’, as after more than a century nearly a quarter of capital is still invested in the high-tech sector, and workers’ migration would only start after 150 years!²¹. Such a high persistence of demand for skilled labour in the presence of a severe skill shortage causes the initial impact of the SBTC on RGI to be positive. Consequently, in the short run, RGI is characterised by an inverted-U pattern *a la* Kuznets (Figure 6), whereas no significant trend can be recognised in CGI, the initial impact of the SBTC being in fact largely negative (GV: Figure 11). Cycles of an average duration of 23 years – thus longer than the ‘normal’ duration of a cycle in this model (see footnote 14 and Fig. 2) - then occur repeatedly for RGI, following a long-term trend of decreasing inequality. The CGI dynamics is instead made more erratic by the interplay between wages and profits and the frequent reshuffles in

²¹ In the scenario characterised by a less pronounced productivity premium, instead, the initial impact on κ is negative and the migration towards the unskilled intensive sector starts much earlier than here (see GV: Fig. 11).

their relative rankings (GV: Fig. 18). As the workforce shifts to the low-tech sector, both inequality indexes settle on their steady state levels²². As fully documented in GV (Appendix, Table 6), even in this case the dynamics in the skill differential is the major driving force for RGI, although unskilled labour unemployment significantly affects RGI as well.

This scenario, though no secular Kuznets curve occurs, clearly highlights the possibility of fluctuations in income inequality that present the inverted-U shape typical of the Kuznets I and II accounts. However, analysis reveals that the underlying economic mechanism is indeed different from that on which the traditional Kuznets accounts are grounded. No shift in workforce takes place here, as the adjustment costs prove too high to induce workers to abandon the low-tech sector. Instead, they are the components of the sectoral business cycle, the intersectoral allocation of capital, and the tensions triggered in the labour market as a consequence of the ISBTC shock, which play a major role. By way of illustration, what causes the fluctuations in RGI in the short run is the following mechanism. The productivity advantage of the high-tech sector keeps skilled labour demand constantly high, which triggers a rise in the wage premium. This is what causes labour income inequality to increase in the short run. The wage differential rise is such as to offset the inequality-decreasing effect due to the reduction of unemployment, which is caused by the economy being in a phase of expansion in both sectors initially. Once the economy has entered a phase of recession, then, inequality rises even more quickly. Subsequently, the economy enters a phase of expansion in the low-tech sector, whereas the high-tech sector is approaching a phase of recession, so the wage differential reduces. Since the low-tech sector weighs more than the high-tech, the overall effect is to reduce labour income inequality. Similar mechanisms, which are led by the sectoral business cycle in the process of adjustment

²² The steady state value for RGI and CGI is different from the initial value observed in this scenario. In particular, RGI measures 0.074 and CGI is equal to 0.187 in the steady state. See also footnote 16.

triggered by the ISBTC shock, also hold for the short-term fluctuations in inequality observed in the scenarios illustrated in section 3.

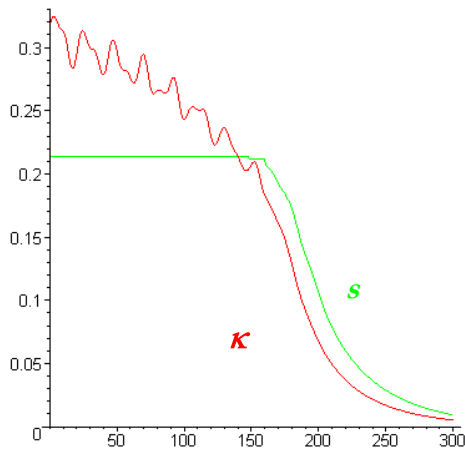


Figure 5: Evolution of skill-intensive capital share and skilled labour supply share (third scenario)

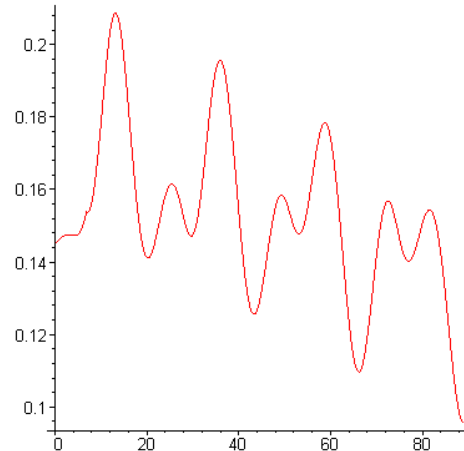


Figure 6: Evolution of RGI (third scenario)

5. Conclusions

On the basis of the analyses carried out in the previous sections, the following conclusions can be put forward.

- 1) The modern interpretation of Kuznets Law (Kuznets II) – originally devised for the developed countries – can also be applied to globalised middle-income DCs characterised by ISBTC and catching-up (that is, the capacity to converge to high-tech sectors in the long run). However, in order for this to be the case, it is necessary that the process of migration towards the skill-intensive sector of the workforce be slowed down by sizeable adjustment costs.
- 2) Alongside this long-run Kuznets curve, short-term ‘micro’ Kuznets curves also emerge. These are associated with the economy’s business cycle; in particular, their determinants are the inter-sectoral dynamic of capital allocation, which determines labour demand; the evolution of the labour income share and of sectoral unemployment; the wage differential. All of these factors are affected by the ISBTC.

3) In the case of lock-in globalised DCs (those unable to converge to the high-tech pattern of growth), no long-run Kuznets curve emerges, as workers do not migrate to the high-tech sector of the economy due to adjustment costs being too high. In particular, RGI may exhibit a decreasing trend right from the start. However, if the productivity differential of the ISBTC is sufficiently high, then a small-scale Kuznets curve analogous to those occurring in the alternative scenario can be detected in the short run.

On the whole, this study shows that the observed increase in WCII in many globalising middle-income DCs in the '90s can be interpreted as the first segment of a short-term Kuznets inverted-U curve. However, this dynamics can be originated either by a skill-biased technological transition similar to the one detected in developed countries (catching-up; see Section 3), or by a 'regressive' dynamics without any catching-up and skill-upgrading in the long run (lock in; see Section 4).

What turns out to be problematic is that these two scenarios are observationally equivalent in the short run and apparently consistent with the long-term pattern of structural change described by the Kuznets II account. Yet, it is obvious that the policy-maker's agenda should be very different. A mere reliance on redistributive policies may suffice in scenario 3 in order to alleviate the social costs of inequality, especially when the time necessary in order to reach the 'peak' of the Kuznets curve – and thus to start the redistribution of the benefits of growth to those social groups that have initially been 'left behind' - is too long, due to the adjustment costs. Structural reforms would instead be needed in the scenario of Section 4 to prevent the economy from being locked-in to a poverty trap. In particular, policies promoting the skill upgrading of the workforce and of the local entrepreneurial forces, and in general those policies facilitating inter-sectoral migration – which in fact may also imply geographical migration - appear as necessary steps for breaking out of a technological lock-in.

6. Appendix: Results of the Regressions on Observations Derived from Simulations

In the following regressions, we have expressed the variables in logarithms in order to remove the effect due to the wage differential following an exponential trend. Whenever problems of serious collinearity appear to emerge, we have omitted in turn each of the regressors being strictly collinear with others. Standard deviations are reported in parentheses. Levels of significance are indicated as follows: *** denotes 99% significance; ** denotes 95% significance; * denotes 90% significance.

Table 1: Analysis of scenario section 3.1 (A Kuznets curve scenario as a result of a ‘progressive’ technological catching-up)

| | Dependent variable: RGI | | | | | Dependent variable: CGI | | | | | | |
|-------------------------------|-------------------------|---------------------|---------------------|---------------------|----------------------|-------------------------|---------------------|---------------------|----------------------|---------------------|----------------------|----------------------|
| | (a) 0-66 | (b) 66-106 | (c) 66-106 | (d) 106-200 | (e) 106-200 | (f) 0-66 | (g) 66-120 | (h) 66-120 | (i) 66-120 | (l) 120-200 | (m) 120-200 | (n) 120-200 |
| Constant | -2.010 | -1.795 | -0.631 | -0.051 | -1.838 | -2.289 | -1.499 | 0.628 | -1.111 | 0.614 | -1.396 | -2.046 |
| Wage premium | 1.120*** (0.169) | 0.491*** (0.140) | - | -0.364 (1.120) | -0.329 (1.120) | 0.799*** (0.169) | 1.117*** (0.242) | - | - | -0.107 (0.968) | -0.072 (0.968) | -0.067 (0.968) |
| Skilled labour unemployment | 0.137 (0.136) | 0.381*** (0.050) | 0.329*** (0.050) | 0.601*** (0.170) | - | 0.096 (0.136) | 0.616*** (0.077) | 0.562*** (0.077) | 0.432*** (0.077) | 0.713*** (0.089) | - | - |
| Unskilled labour unemployment | 0.201** (0.120) | -0.050 (0.333) | 0.002 (0.333) | -0.023 (1.334) | -0.030 (1.334) | 0.147 (0.196) | -0.027 (2.373) | 0.011 (2.373) | 0.016 (2.373) | - | - | - |
| Percentage of skilled workers | - | - | 0.577*** (0.147) | - | -0.776*** (0.187) | - | - | 1.097*** (0.217) | - | - | -0.875*** (0.111) | - |
| Labour income share | - | - | - | - | - | -2.830*** (0.025) | - | - | -1.737*** (0.139) | - | - | -1.555*** (0.066) |
| R ² | 0.99994 | 0.99992 | 0.99996 | 0.99966 | 0.99976 | 0.99991 | 0.99912 | 0.99955 | 0.99976 | 0.99964 | 0.99986 | 0.99997 |
| N | 660 | 400 | 400 | 940 | 940 | 660 | 540 | 540 | 540 | 800 | 800 | 800 |

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