Innovation and income inequality[1]

Cristiano Antonelli[*]

Agnieszka Gehringer[**]

[*]*Dipartimento di Economia, Università di Torino & BRICK Collegio Carlo Alberto.*

[**]*Volkswirtschaftliches Seminar, Lehrstuhl für Wirtschaftspolitik, Georg-August-Universität Göttingen*

Abstract. The paper articulates and tests the hypothesis that innovation is a major factor in the reduction of income inequalities. The relationship between the pace of technological change and the dynamics of income inequalities has been first suggested by Kuznets (1955), but found little elaboration and empirical investigation in the subsequent literature. The evidence of a large data set including advanced countries, such as the US, Canada and the members of the European Union, as well as the newly industrializing BRIC members, in the years 1995-2011, confirms the virtuous circle between technological change and income inequalities.

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1. Introduction

The paper elaborates and tests the hypothesis that technological change is a powerful factor that reduces income inequality. Technological change helps reducing income inequalities for two reasons. First, because it magnifies the rates of economic growth and hence the increase of wage levels complementing the traditional hypothesis that economic growth reduces income inequalities. Second, due to the dynamics of market rivalry based upon innovation, the higher the price competition of factor and product markets and the lower the accumulation of rents and hence the increase of income inequalities. At the same time, however, it should be kept in mind that income distribution affects the rates of technological change: lower levels of income inequality increase the incentives and opportunities of increasing human capital and hence a new pool of knowledge externalities sustaining innovative activity is freed up for the economic system.

The analysis of the causes and effects of the distribution of income and specifically of income inequality is a long discussed issue in economics. Large empirical evidence discusses episodes of increasing income inequality both in advanced and industrializing countries since the end of the XX century (Aghion, Caroli, García-Peñalosa, 1999; Kaplan and Rauh, 2010). The raising levels of income inequality have called increasing attention especially to try and understand its determinants. Among other determinants, the past literature has focused on the direct effects of the output growth. Quite surprisingly little attention has been paid to appreciating the role of indirect growth effects and most importantly, of technological change, as the main source of economic progress.

The rest of the paper is structured as it follows. Section 2 explores the relations between technological change and income distribution and articulates the hypothesis that the rates of introduction of technological and organizational innovations have significant impact in reducing income inequality. Section 3 presents the empirical evidence and the results of econometric investigations that confirm the negative relationship between the rate of technological change and the levels of income inequality in an inclusive data set comprising all the EU countries, USA, Canada, Japan, Turkey, Croatia, Island, Norway, Switzerland and the BRIC countries (Brazil, Korea, China, India). The conclusions section summarizes the results and elaborates policy implications.

2. Technological change and income distribution

2.1 The standard view over economic growth and income inequality

After more than fifty years, the pathbreaking contribution of Simon Kuznets (1955, 1963) remains the basic reference in the economics of income inequalities, for many reasons. First and most important reason has to do with the identification of the issue: income distribution is a relevant aspect of the economic structure of every economic system. Second, it is not static, but intrinsically dynamic as it keeps changing simultaneously throughout economic history and across countries (Aghion, Caroli, García-Peñalosa, 1999). Third, it is not exogenous but, quite on the contrary, the endogenous consequence of the structure and dynamics of the economic system. Fourth, and more specifically, income distribution stems from the distribution and remuneration of three well distinct factors: capital, labor and skills.

Income distribution, in other words, should be investigated over two dimensions, the functional one and the personal one. The first one concerns the distribution of income between the main factors of production, i.e. capital and labour. It depends upon the distribution of profits and dividends paid to capital owners as well as of wages and wage premiums paid to the levels of human capital embedded into skilled labor. The second one pertains the distribution of income among households (or individuals), irrespective of the source of income.

Building upon these pillars, Simon Kuznets elaborates an interpretative framework, where income distribution reflects the changing distribution of wealth and skills and their changing prices with respect to standard labor that takes place along economic growth. While the methodological foundations of the analysis are still valid, the specific contents of his analysis are quite dated by now. Kuznets, indeed, paid much attention to the changing structure of the economic systems at the time of industrialization, with the rapid shift away from an agricultural and rural economy into an urban and industrial one.

On such a historical background he noted that, in the early phases of industrializations, income inequality increases because of the large differences in factor productivity between rural and urban activities. Afterwards, however it eventually declines with the completion of the industrial transformation. Once the full system has been able to complete the industrial transformation the standard dynamics of economic growth favors the reduction of income inequality along the following chain of factors: 1) savings increase the supply of capital 2) and decrease the levels of interest rates; 3) capital intensity increases, and 4) labor productivity increases (with the appropriate supply of complementary skilled workforce), 5) leading to higher wages that make possible a larger supply of savings; 6) moreover, in an advanced industrial economy, tighter competition in product and factor markets makes it possible to minimize monopolistic profits. Figure 1 synthesizes the working of the mechanism that relates economic growth to the reduction of income inequality. Following this chain of factors it appears clearly that the standard mechanism of economic growth reduces income inequality by means of the decrease of interest rates, the reduction of monopoly profits and the increase of wages. Hence, the famous inverted U-shaped relationship between income inequality and revenue per capita, initially suggested by Kuznets (1963), acquires a fresh understanding.

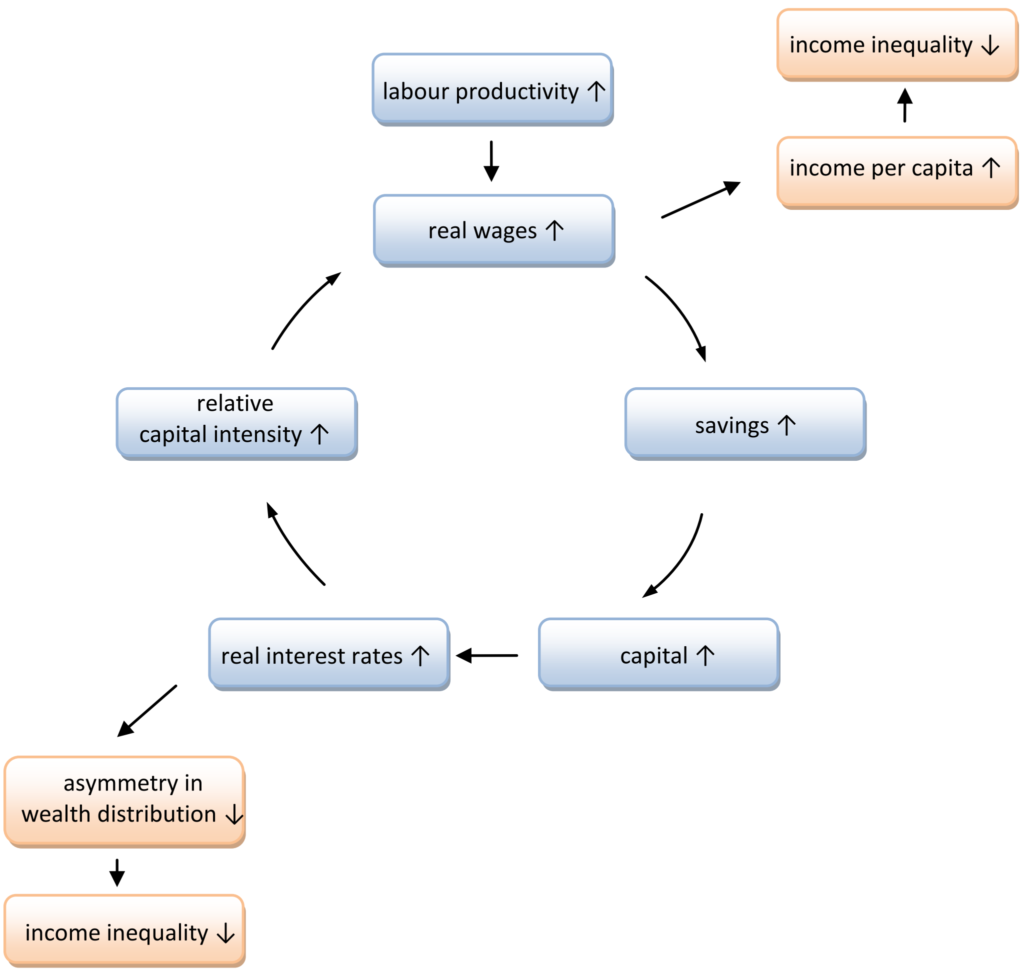

Figure 1 Economic growth and income inequality in the standard view.

The empirical literature provides contrasting evidence on the issue. The inverted U-shaped relationship between the stage of development and income inequality finds only partial support and seems to be quite sensitive to the composition of the datasets and the time periods analyzed (Adelman and Robinson, 1989; Atkinson and Piketty, 2007 and 2009). Dollar and Kraay (2002) conclude their inclusive study, extended to all the countries of the Penn World Tables, that there is no systematic evidence confirming economic effects on the income distribution. There is, instead, converging evidence about the positive effects of income growth on the reduction of income inequality, especially in developing countries (Adams, 2002; Chen and Ravallion, 2001; Ravallion, 1995). The evidence about advanced countries is on the opposite mixed, especially, when the last decade of the XX century is considered (Atkinson and Pikkerty, 2009). As a matter of fact, Kaplan and Rauh (2010) show that income inequality has increased in the recent past at a time of fast economic growth.

The theoretical literature has shared the basic intuitions that support Kuznets analysis. By articulating and expanding his basic hypothesis, past theoretical contributions show consensus on the fact that in the long-run the economic growth process reduces income inequality. An emphasis here was put towards the appreciation of the role of equilibrium conditions. Accordingly, the closer are the working of product and factor markets- including financial markets and all considered in the national and global dimension - to competitive equilibrium and the lower the income inequalities. When economic growth is associated with an increase of market imperfections, income asymmetry would actually increase.

These results stem directly from the appreciation of the factors that account for economic growth in the standard framework. According to traditional growth theory, in fact, economic growth is engendered by the increased availability of capital via the accumulation of savings and the consequences in terms of lower interest rates and increased capital intensity of production processes. All imperfections of financial markets have strong negative effects on the correct allocation of resources favoring inefficiency that discriminate income distribution in favor of the wealthy (Aghion and Bolton, 1992). All measures that remove frictions from the financial markets and, hence, improve the availability and efficiency of capital, for given levels of savings, are likely to favor the reduction of interest rates, and finally, the increase of capital intensity. The consequences for income distribution in terms of reduction of income inequality are straightforward and strongly complementary because the reduction of interest rates shrinks the effects of the possible -actually frequent- asymmetries in the distribution of wealth that are, in relative terms further reduced by the increase in the wage levels (Beck, Demirgüç-Kunt, Levine, 2007).

Within the same interpretative framework it is clear that the increase in competition both in domestic and international product markets is likely to affect positively the rates of economic growth. This works through the positive effects in terms of both more rational allocation of resources, improved division of labor, as well as specialization.

The exposure to international competition is especially effective to reduce and sometimes overcome the barriers to entry and to mobility. Such barriers limit competition in domestic markets, and consequently, the overall growth dynamics. Greater foreign competition, visible through the increase in imports, makes markups decline and, thus, also profit margins fall (Chen *et al.*, 2009). The relationship has been found effective both for exports and imports. Large empirical evidence confirms the positive relationship between the share of imports to GDP and competition (eg. Mac Donald, 1996). For the same token, the larger are the shares of exports to GDP and the higher the levels of international competiveness and the closer the conditions of product markets to the standards of workable, if not perfect competition. It is consequently clear that the larger are levels of the openness to trade - as measured in terms of the share of imports and exports to GDP - the closer the levels of prices to minimum average costs and the lower the levels of mark-ups and quasi rents. Low levels of mark-ups and quasi-rents insure that the distribution of income is close to competitive levels, with capital and labour remunerated on their marginal productivities. Firms, and consequently firm owners, cannot accumulate profits. In financial markets, interest rates are less inflated by profit margins. It becomes evident - following this chain of arguments- that the larger are levels of openness to international trade and the lower are the income inequalities (Wood, 1994; Roine, Vlachos, Waldenstrom, 2009).

Careful analysis of international economics, however, provides an opposite argument. Openness to trade in capital abundant countries may have a positive effect on income inequality. This might come as a consequence of the increase of imports from labor-abundant countries, where more capital intensive techniques are applied, in turn, increasing the derived demand of capital and help interest rates to rise. Ultimately, asymmetric effects in the income distribution would stem from the increasing share of the wealthy citizen of capital abundant countries (Manasse and Turrini, 2001).

The empirical evidence on the effects of openness to trade on income inequality confirms that the effects on income inequality are prevalently negative when trade takes place horizontally among advanced countries (reference). The evidence about the effects of horizontal international trade confirms the basic intuition that extra-profits and quasi-rents play a central role in increasing income inequality. The possible explanation for this is that the horizontal trade flows free up capacities and permit to take advantage from economies of scale. As a consequence, increasing market shares lead to an increase in market power and, finally, higher extra-profits in the hands of few. The closer are the conditions of product and factor markets to competitive equilibrium and the lower are the chances that the accumulation of profits may help increasing income inequality.

It is important to note that the ultimate result of the different strands of the literature that analyze the relations between economic growth and income inequality confirm the key role of the reduction of market imperfections and specifically of monopolistic rents in reducing the levels of income inequalities. In the static framework of analysis, shared by a large part of this literature, there is a strong and clear causality between the levels of imperfections of product and factor markets, the levels of profits, hence, the asymmetric accumulation of rents into long-lasting wealth and ultimately income inequalities.

Much broader framework, however, is necessary as soon as we acknowledge the role of technological change as an intrinsic component of economic dynamics (Crenshaw, 1992).

2.2 Innovation dynamics and income distribution

After years of neglect, the effects of technological change on income distribution have been recently taken into consideration. The first step has been when the direction of technological change - defined in terms of changes in the output elasticity of production factors - determined by the introduction of biased technological change, has been considered. This took place in the context of the skill-biased technological change hypothesis. In this context, the skill-bias has been found as an important factor responsible for the increase of income inequalities, observed in the new century. According to this literature, the introduction of new technologies, strongly biased in favor of skilled labor, might have determined an increase in income asymmetry because of the increasing divergence of wages between skilled and un-skilled labor (Vanhoudt, 2000).

This approach, as most of the skill-bias hypothesis, however, misses to appreciate the strong capital saving characteristics of the skill-biased direction of technological change. This second, contemporary and complementary bias of the new direction of technological change should reduce the derived demand for fixed capital and hence, for given amount of available capital, interest rates should fall. Consequently, the reduction of income stemming from wealth would contribute to diminishing income asymmetries between income holders. The appreciation of this second effect should mitigate, if not overcome, the claim that skill-biased technological change increases income inequality. The net effect stems, in fact, from the balance between the asymmetry-increasing effects stemming from the increased remuneration of skills, and the asymmetry-decreasing effects stemming from the reduction of interest rates.

In sum, following the distinction of Aghion, Caroli, García-Peñalosa (1999), the skill-biased-technological-change hypothesis may increase wage inequalities rather than income inequalities.

Most importantly, however, not only the direction, but also and most importantly the rate of technological change does play a role in determining economic growth. Consequently, it directly might have an impact on income distribution. Economic growth is not determined only by the well-known virtuous relationship between labor productivity, income per capita, savings, increase in the amount of capital, reduction of interest rates, increase of capital intensity, increase of wages and increase of labor productivity. The introduction of technological innovations is the second and actually the most important determinant of economic growth. Kuznets was well aware of the crucial and endogenous role of technological change both in fostering economic growth and in reducing income inequality. The effect of technological change is strong as it works both indirectly via the positive effects in terms of increase of labor productivity and directly as crucial factor in reducing market imperfections.

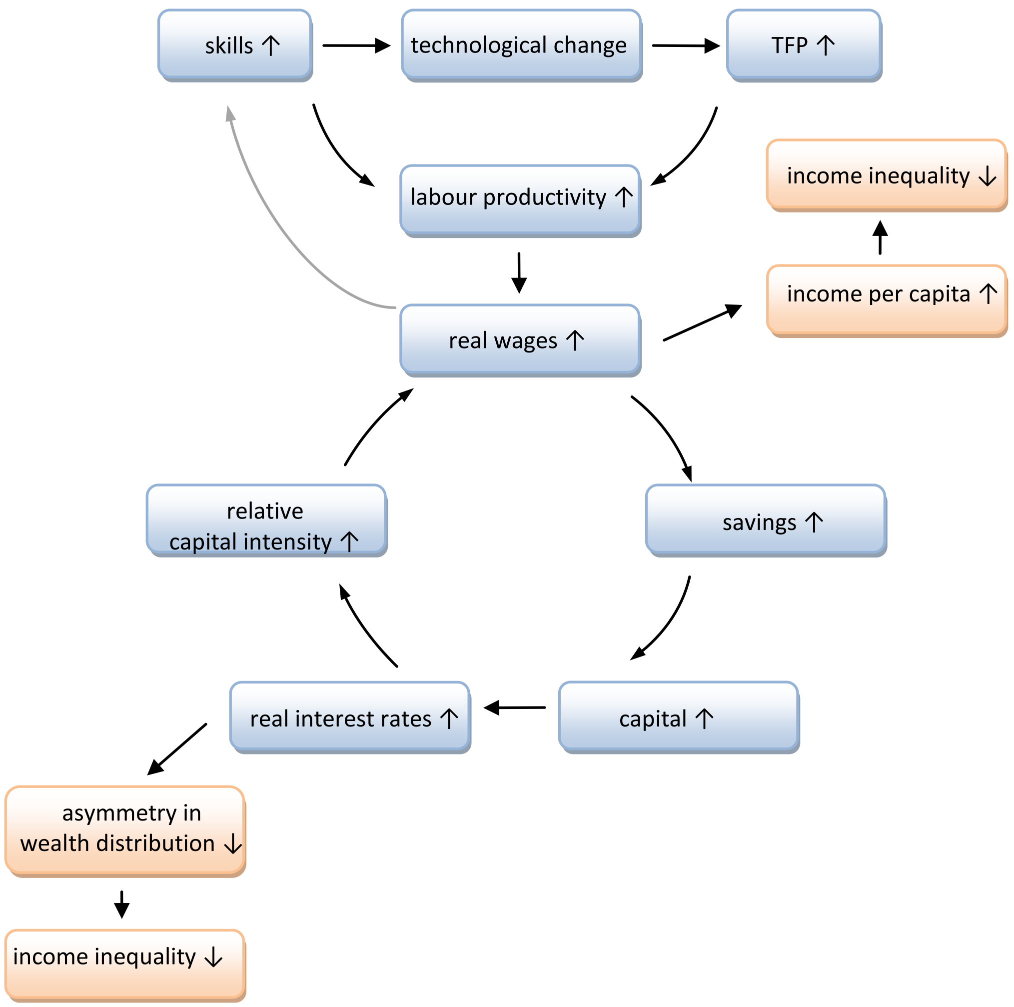

Figure 2 Innovation dynamics and income inequality.

Nevertheless, the literature after Simon Kuznets has been mute on this relationship. This is quite surprising if one recalls the importance given by Kuznets to technological change. According to Kuznets, technological change affects the composition of the stock of wealth reducing the share of incumbents and increasing that of newcomers: “In such a society, technological change is rampant and property asset that originated in older industries almost inevitably have a diminishing proportional weight in the total because of the more rapid growth of younger industries. Unless the descendants of a high-income group manage to shift their accumulating assets into new fields and participate with new entrepreneurs in the growing share of the new and more profitable industries, the long-range returns on their property holdings are likely to be significant lower than those of the more recent entrants into the class of substantial asset holder” (Kuznets, 1955: 10).

2.3 Schumpeterian view on inequality reducing technological change

The analysis of the effects of technological change on income distribution in terms of reduction of income asymmetries can be reviewed and strengthened by the basic contributions of Schumpeter (1934 and 1942). According to Schumpeter, innovation is not an occasional characteristic of the evolution of an economic system but an intrinsic component and the key determinant of its dynamics. The introduction of innovation is at the basic imperfections in product markets. Innovators command quasi-rents that last as long as the entry of imitators is impeded by barriers to entry and cost differences between incumbents and potential entrants. Increasing returns based upon learning economies and economies of scale, in fact, provide incumbents with increasing cost advantages that delay market entry based upon imitation. The strategic pricing of incumbents can stretch the duration of monopolistic rents with the reduction of prices below the costs of potential entrants and imitators. This could eventually favor the increase of demand and the diffusion of product innovations. In this context, only the introduction of new technological innovations by potential competitors may reduce the duration of monopolistic quasi-rents. New products and processes make possible the creative destruction with the substitution of new quasi-monopolies to the old ones. In this analytical framework, only the introduction of innovations on a regular basis, and more generally, the positive rates of technological change may impede the formation of long-lasting quasi rents based on previous vintages of technological innovations. Only the rate of technological change can increase the actual levels of rivalry, as distinct and opposed to competition.

According to Schumpeter (1947) firms caught in out-of-equilibrium by unexpected changes in factor and product markets try and react. Their reaction will be merely adaptive if appropriate levels of skills and knowledge externalities are not available. When instead the levels of human capital and skills of manpower are large enough and support high levels knowledge externalities, the attempts of firms to react to un-expected changes can be actually creative. Adaptive reactions enable firms to change their techniques i.e. to move on the existing map of isoquants. Creative reaction consists in the actual introduction of new superior technologies that enable to increase the dynamic efficiency of the production process.

In the Schumpeterian framework, the faster is the rate of technological change and the faster the reduction of income inequality. With a slow pace of innovation, monopoly rents, reinforced by the barriers to entry and to imitation, are long lasting and market prices decline towards actual production costs only in the very long term. The transfer of the benefits of technological change, in terms of the overall increased efficiency of the production processes and higher quality of the products - especially if measured in terms of hedonic prices so as to include the effects of product innovations- to consumers is very slow. Innovators can retain for themselves large shares of these benefits and increase income inequality both via the increase of their current incomes and the related increase of their wealth with long lasting effects on the income inequalities in the future.

When instead the introduction of product and process innovations is fast, the monopolies and related quasi-rents impinging upon the previous vintages of innovations, last much less. The transfer of the benefits to consumers is much faster. The duration of the accumulation of quasi-rents is much smaller. The lower levels of income inequalities favor the accumulation of human capital that reinforces the rates of technological change. The Schumpeterian framework of analysis confirms the hypothesis put forward by Kuznets: the faster are the rates of introduction of innovations and the lower are income inequalities.

Only the introduction of a new vintage of technological innovation can overcome the barriers to entry and destroy the competitive advantage of incumbents. Fast rates of technological change make it possible the working of the creative destruction and the transfer to consumers of all the advantages of the new technology. Slow rates of introduction of technological innovations, on the opposite, may engender long lasting barrier to entry and, hence, impede the working of price competition with the consequent accumulation of quasi-rents and ultimately the increase of income inequalities both in terms of current profits and increase rents, stemming from accumulated wealth.

Technological change contributes to the reduction of income inequalities not only because its rates trim the duration of transient quasi-rents associated to previous technological vintages, but also because it is the main source of increase of economic growth with the increase of the general efficiency of production processes. Technological change is at the origin of the increase of total factor productivity that, in turn, leads to higher levels of labor productivity and, consequently, to higher levels of savings. The latter make possible the increase of the stock of financial resources available for investment, the consequent reduction of interest rates, the increase of wages and, hence, the reduction of income from wealth that is at the main origin of income inequalities.

The causal relationship between technological change and income distribution works both ways. So far we have seen why and how technological change helps reducing income inequalities. Now, following Schumpeter (1947) we can appreciate how and why income inequality slows the rates of technological change. As soon as we stop considering technological change as an exogenous event and we fully apply the Schumpeterian approach - according to which technological change is endogenous to economic dynamics as it is at the same time the cause and the consequence of technological change - we can see that the relationship between technological change and income inequality works both ways.

The amount of skills and the levels of human capital embedded in the working population play a crucial role in the Schumpeterian framework of explanation of the endogenous origin of technological change. Following Aghion, Caroli, García-Peñalosa (1999) it seems clear that income inequality prevents, delays and reduces the levels of human capital in a given economic system. The concentration of income impedes the access of large shares of the population to training and reduces the chances to identify agents with high potential levels.

Economic systems with low levels of income inequality have larger chances to improve the levels of human capital and learning. Higher abilities of the workforce provide firms - that try and react to un-expected shocks in factor and product markets - with larger and better knowledge externalities. Hence, the chances that the reaction of firms becomes creative, is clearly related to the levels of human capital. In sum, it seems now evident that faster rates of introduction of innovations lead to lower levels of income inequalities and lower levels of income inequalities lead to faster rates of introduction of innovations.

2.4. The hypothesis

We can now spell clearly our hypothesis: technological change plays a crucial role in shaping the distribution of income. The rate of technological change and income inequalities, in fact, are tightly intertwined by three well distinct processes: first, innovation helps sustaining the rates of economic growth, also through increasing labor productivity and, thus, the increase of wage levels. This complements the traditional hypothesis that economic growth reduces income inequalities. Second, the dynamics of rivalry based upon innovation complements and widens the hypothesis that the higher the competition in factor and product markets and the lower the accumulation of rents and, hence, the increase of income inequalities. Thirdly, income inequality slows down the rates of innovation. Income inequality, in fact, reduces the opportunities to increase the levels of human capital and the accompanying knowledge externalities. Larger stocks of human capital favor the accumulation of knowledge and ultimately the introduction of innovations. Technological change and income inequality are strongly related by a virtuous cycle where both elements are part of an endogenous self-reinforcing dynamic process.

3. Empirical evidence

3.1 Econometric strategy

The previous discussion on the link between income inequality and growth suggests that there are numerous conceptual and methodological caveats to be taken into account. First, from the conceptual point of view, the link between inequality and innovation is shaped by a two-way causality that challenges the estimation strategy with obvious endogeneity problems. Consequently, the choice of the right methodology should be at the center of our analysis.

Second, it seems not an obvious choice to apply an adequate measure of technological change. Most importantly, due to the complex and manifold nature of technological change, we recognize that there does not exist a unique indicator optimally measuring it. Consequently, there are more than one of them, yet each presenting its advantages and limitations. Among possible candidates there are data based on R&D expenditures, a typical input measure that has been more and more criticized for its limitations. The recent advances in the literature stress that, next to R&D inputs, many other relevant inputs play a central role in the generation of new technological knowledge and in the eventual introduction of innovations. Total factor productivity - an alternative indicator of the intensity of technological change - suffers from too many equilibrium assumptions that risk to limit its reliability in a context characterized by long-term development with major changes in the structure and organization of the economic systems considered.

Our choice is to make use of patent counts, a typical measure of the output of the innovative process, which seems to be able to approximate well the generation of technological knowledge actually dedicated to economic applications. Specifically we regard the number of patent applications made each year as our main measure of the rate of technological change. This is a flow measure that directly reflects increase in the stock of technological knowledge available in an economic system.[3] As such, patent data are potentially more precise than other measures of innovation, as they refer to concrete and successfully terminated research and development efforts. Accordingly, patents have been extensively used in the management and economics literature to measure knowledge flows (e.g., Jaffe et al., 1993 and 1998; Almeida and Kogut, 1999; Popp, 2003 and 2005; Alcacer and Gittelman, 2006).

Second, we bear in mind the many issues - and limitations - connected with the measurement of income inequality. In particular, Aghion et al. (1999) make the central distinction between *wealth* versus *wage* inequality. They argue that in the investigation of the effects of growth on inequality it is more relevant to account for the distribution of wages as distinct from the distribution of capital income. On the other hand, however, it might be equally reasonable to investigate the impact of (in our setting) productivity growth on inequality at the level of households, where the focus is on wealth, independently of its sources. This is also what we are going to stress on in our analysis, most importantly due to the data availability issue. Indeed, we will apply the Gini coefficient or, alternatively, the quintiles of income distribution (or the ratios between them), where the definition of income, according to Eurostat, is the one of the total disposable income of a household. This is calculated by summing up the personal income gained by each member of a household and non-labour income received at the household level. In that way, disposable income includes: income from work (wages of employed persons and earnings by self-employed), private income from investment and property, transfers between households, all social transfers received in cash (including old-age pensions).

Finally, there are reasons to prefer multi-year averaged data to annual observations. First, given that some of our variables are expressed in terms of growth rates, they might be excessively noisy in the annual frequency. Second, by averaging the annual observations, we avoid the possible influence of the business

[3] We recall the relevant literature dealing with the respective advantages and drawbacks connected with the use of patent data to measure productivity (see, for instance, Griliches (1990), Napolitano and Sirilli (1990), Popp (2005)). Nevertheless, in our context, where we are particularly interested in the distribution of income, the count of patents seems to measure the remunerable technological change more reliably than some measure of factor productivity, be it TFP growth or labour productivity growth.

cycle that potentially would enter the analysis on the annual data. Third, the estimations based on multi-year averages are more adequate to offer medium-term conclusions in the investigation of the underlying hypothesis. Consequently, to study our main specifications, we transform our annual data into 4-year averages.[4]

Keeping in mind the aforementioned considerations, the general model to be estimated takes the following expression:

$$Ineq_{it} = Tech_{it} + inv_{it} + GDPcap_{it} + \ gov_{it} + FI_{it} + \ \gamma_t + \varepsilon_{it} \tag{1}$$

where: *Ineq* refers to an indicator of income inequality in country *i* at time *t* (where t refers to each of the four 4-year averaged time periods), *Tech* stays for technological change, *inv* is total investment, *gov* measures the government spending - both in percentage of GDP - *FI* is an indicator of international financial integration and *GDPcap* stays for GDP per capita. Finally, γ_t and ε_{it} are time-invariant effects and indiosyncratic error terms, respectively.

We do not include country-invariant factors to permit that such country characteristics enter the interactions between the dependent and explanatory variables explicitly included. Indeed, the inclusion of country specific effects would subtract much of the cross-sectional variability, in which we are highly interested in our setting.[5]

We estimate our baseline specifications with feasible generalized least squares (FGLS) methodology, allowing for country specific serial correlation in the error terms. Our choice is driven by the fact that we detect serial correlation in the residuals. Alternatively, a dynamic structure of the model, obtained by the inclusion of the lagged dependent variable, would take serial correlation directly into account. Nevertheless, the results from such a dynamic estimation would be biased due to correlation of the lagged dependent variable with the time-invariant country-specific effects. This bias is the larger the shorter is time period considered (Nickell, 1981). In our setting, where T=17 and we, moreover, transform the data into 4-year averages, the bias is expected to create major concerns.

A valid solution to this would be to apply difference or system GMM method, permitting to incorporate dynamics into the model and at the same time get rid of time-invariant effects through first-differencing the model. The method has been originally designed for small-T, large-N panels, whereas ours has a rather balanced T-N structure. This notwithstanding, we applied system GMM method and the results were comparable to those from the FGLS estimations. Nevertheless, the Sargan test for overidentifying

[4] There is no consensus regarding the use of 4- or 5-year averages, although the latter have been more often investigated, but often without motivating much the choice. We derive 4-year averages in the way to maximize the number of observations per country. Consequently, although our database ranges between 1995 and 2011, we exclude 1995, given that there were more missing values than for 2011.

[5] For a discussion on the issue, see, Chinn and Prasad (2003) who investigate the determinants of current account imbalances.

restrictions reported that our instruments were weak.[6] Correspondingly, we report only the results from FGLS procedure.

A satisfactory test of the effects of innovation on income distribution must tackle the endogeneity issues. As we have seen, the likelihood that low levels of income inequality have positive effects on the rates of introduction of innovations is not trivial. This implies that a circular causal relationship between innovation and income distribution is at work. For that reason, innovation can and should be treated as an endogenous variable. Our strategy to tackle this issue consists in re-running our three main specifications with instrumental variable regressions. We instrument the explanatory variables related to technological change with their first and second lags.

3.2 Data description

Our main dependent variable is given by the Gini index, as reported by Eurostat. For countries not covered by Eurostat, we make use of the World Bank Development Indicators database. Gini coefficient is defined as the relationship of cumulative shares of the population segregated according to the level of equalized disposable income to the cumulative share of the equalized total disposable income. According to the Eurostat's definition the total disposable income of a household is calculated by summing up the personal income gained by each member of a household and non-labour income received at the household level. In that way, disposable income includes: income from work (wages of employed persons and earnings by self-employed), private income from investment and property, transfers between households, all social transfers received in cash (including old-age pensions).

Alternatively, however, in the sensitivity analysis, we use instead of the Gini index other measures of income inequality based on quantiles of income distribution. More precisely, following the past literature (ref.!), we consider two ratios, one between the fifth and the first and one between the fifth and the third quantile of income distribution.

The patent variable refers to the ratio between the number of patent applications made each year directly to WIPO and national phase entries and GDP in constant U.S. dollars prices. In this way, we deflate the absolute number of patents by the size of the economy. The Penn World Tables provides also our measure of trade openness (*openk*) and of government spending in percentage to GDP (*kg*). The investment variable (in percentage of GDP) comes from World Economic Outlook. From the same source we took GDP per capita (expressed in millions of PPP current international dollars).

Finally, we apply as a measure of financial integration a *de jure* indicator taken from an updated database based on Chinn and Ito (2008).[7] This indicator is obtained in an estimation procedure, based on a

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[6] Due to a limited number of groups in our panel, we couldn't include too many instruments (Roodman, 2009).

[7] There exist numerous measures of financial liberalization. In particular, there are different *de jure* measures of financial integration (for example, Quinn index of capital account liberalization), but they cover only limitedly the time span and/or countries applied in my analysis. Analogously, Lane and Milesi-Ferretti (2007) develop a broadly used measure of *de facto* financial liberalization that, however, ends in 2004 and thus doesn't cover several years in my observation sample. For a discussion on the advantages and

principal components model. The authors use the data from the IMF Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER). In the construction of the index, information is used on the presence (or absence) of multiple exchange rates, on restrictions on current account and capital account transactions and on the requirement of the surrender of export proceeds. This index covers all the countries and years included in our sample.

3.3 Results

In Table 1 we summarize our main results both from the FGLS and from the IV regressions. Generally, they confirm the evidence of a strong inequality-reducing effect connected with technological change. Moreover, this result is stronger for the sample including only the EU countries (columns 3 and 6). This might be due to the positive effect of the European institutional framework. In particular, both competition and cohesion policies have among their primary goals the enhancement of the quality of life of consumers. Competition policy, indeed, aims at monitoring the operating of effective competition, thus, at limiting the extent of the up-normal rent collection and, consequently, at assuring that the consumers gain the equal part of the economic outcome. Moreover, another aspect of effective competition points to the positive incentive-increasing effect with the potential contribution to the productivity growth. Cohesion policy, instead, operates - among others - through the active sustain of skill-enhancing measures, especially in the social groups being disadvantaged. In this sense, both aim to achieve higher rates of innovativeness and, at the same time, to reduce the extent of income inequalities, either through the increase in wages or through a more symmetric distribution of wealth.

Recalling our conceptual discussion, it seems crucial to focus on the results of the instrumental variable estimations. With this procedure, we are able to test that our results from the FGLS estimations are not affected by the strong presumption of the endogenous character of our main explanatory variable. Looking at the outcome in columns 3-6, we can confirm that the relationship between the rate of increase of the stock of technological knowledge - as proxied by the yearly patent applications - and income inequality is strong and statically reliable. Once again, the negative effects of innovation on income inequality take place also when the potential endogeneity of innovation is taken into account.

Regarding the other control variables, all of them, with the remarkable exception of the index of financial integration, contributed to the reduction of income inequality. In particular, for the trade openness we report negative estimation coefficients, suggesting that intensifying trade relations played a role in reducing income disparities. Given that our country sample is composed both by developed and by still less developed countries, this finding is only limitedly comparable with the outcomes of the past investigations. Consequently, we interpret this result in relation to our specific country composition and less as a support for any particular hypothesis analysed in the past empirical literature.

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drawback connected with using a de jure and non de facto measure of financial integration, see Kose et al. (2009) and Gehringer (2013).

The negative coefficient found for both GDP per capita and for investment strictly relate to our conceptual design previously discussed. Indeed, the increase in GDP per capita, implicitly stemming from the increase in wages, leads to the reduction in income inequalities. Accordingly, more intensive capital accumulation, possible thanks to increase in savings, indirectly leads to a more symmetric distribution of wealth.

Finally, in the second (and fifth for the IV regression) column, we introduced regional dummies relative to three country groups within the EU as well as to BRIC countries. In that way, we assure that the results are not driven by some country-group-specific effects. The main results of the inequality-reducing effects coming from technological change have been confirmed.

Table 1 Income inequality and technological change measured by patent count.

	FGLS			IV		
	(1) all	(2) all	(3) EU only	(4) all	(5) all	(6) EU only
patent	-0.059	-0.074	-0.090	-0.037	-0.074	-0.088
	(0.010)***	(0.014)***	(0.015)***	(0.021)*	(0.028)**	(0.023)***
openness	-0.067	-0.038	-0.045	-0.074	-0.057	-0.053
	(0.007)***	(0.007)***	(0.007)***	(0.014)***	(0.012)***	(0.010)***
GDPcap	-0.211	-0.143	-0.115	-0.260	-0.197	-0.151
	(0.030)***	(0.031)***	(0.042)**	(0.063)***	(0.046)***	(0.072)**
investment	-0.364	-0.346	-0.238	-0.445	-0.344	-0.242
	(0.058)***	(0.044)***	(0.064)***	(0.166)**	(0.128)**	(0.156)
gov expend	-0.436	-0.318	-0.341	-0.458	-0.316	-0.221
	(0.030)***	(0.039)***	(0.042)***	(0.066)***	(0.071)***	(0.085)**
FI	0.335	0.810	0.213	0.791	1.430	1.324
	(0.235)	(0.177)***	(0.335)	(0.484)	(0.528)**	(0.757)*
BRIC		9.751			10.206	
		(2.174)***			(3.049)**	
Core-EU		-0.073			-0.280	
		(0.577)			(1.312)	
East-EU		-0.258			-1.108	
		(0.787)			(1.112)	
South-EU		0.933			-0.197	
		(0.531)*			(1.102)	
N. obs.	130	130	75	69	102	38
Wald chi-sq	471***	570***	470***			
R-squared				0.657	0.719	0.641

Note: Dependent variable is Gini index. All variables are 4-year averaged over the time span 1996-2011. Time fixed effects are included in all specifications. ***, ** and * refer to 1, 5 and 10% significance level. Standard errors are reported in parenthesis. Specifications in columns 1-4 have been run according to FGLS method, allowing for country-specific serial correlation and heteroskedasticity in residuals. In columns 5 and 6 we apply instrumental variable approach, with patent variable instrumented with its first and second lags.

3.4 Sensitivity analysis

Estimations on annual data and other measures of productivity

It might be argued that the estimation based on multi-year averaged data covers the true relationship between the investigated variables. Although we are convinced about the great advantages connected with considering tendencies over the cycle, to strengthen our previous results, we re-estimate the basic specifications using the annual observations.

The results for the patent count variable previously, used as our main measure of the rate of technological change, are analogous to those seen previously.

Table 2 Income inequality and technological change – estimations on annual observations.

	FGLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
patent	-0.076			-0.086		
	(0.008)***			(0.015)***		
ΔTFP		-0.223			-1.019	
		(0.075)**			(0.349)**	
Δlab			-0.111			-0.348
			(0.052)**			(0.136)**
openness	-0.057	-0.043	-0.047	-0.076	-0.046	-0.053
	(0.005)***	(0.004)***	(0.004)***	(0.008)***	(0.006)***	(0.007)***
GDPcap	-0.181	-0.159	-0.176	-0.230	-0.197	-0.180
	(0.022)***	(0.018)***	(0.021)***	(0.033)***	(0.031)***	(0.027)***
investment	0.273	0.079	-0.084	-0.358	-0.158	-0.119
	(0.040)***	(0.034)**	(0.038)**	(0.077)***	(0.067)**	(0.055)**
gov expend	-0.414	-0.406	-0.434	-0.408	-0.461	-0.439
	(0.022)***	(0.018)***	(0.019)***	(0.033)***	(0.035)***	(0.028)***
FI	0.252	0.721	0.663	0.284	0.524	1.014
	(0.173)	(0.179)***	(0.199)**	(0.331)	(0.347)	(0.303)**
N. obs.	390	359	335	353	324	302
Wald chi-sq(20)	1021	751	790			
R-squared				0.589	0.419	0.547

Note: Dependent variable is Gini index. All variables are annual observations over the period 1995-2011. Time fixed effects are included in all specifications. ***, ** and * refer to 1, 5 and 10% significance level. Standard errors are reported in parenthesis. Specifications in columns 1-3 have been run according to FGLS method, allowing for country-specific serial correlation and heteroskedasticity in residuals. In columns 4, 5 and 6 we apply instrumental variable approach, with *patent, ΔTFP* and *Δlab* variables instrumented with first and second lags.

Additionally, we introduce here alternative measures of productivity dynamics, namely, TFP growth and labour productivity growth. Our measure of TFP is an index (2005=100) provided by Ameco database. To measure labour productivity, we construct an index (2005=100) based on a variable given by the ratio between GDP at constant prices and the number of employees. Data to calculate labour productivity are also taken from Ameco database. Although, due to the reasons previously discussed, we recall the need to interpret these results with caution, we could confirm the beneficial contribution of productivity growth to the reduction of income inequalities. Also for the great majority of the other control variables, the effects previously observed re-emerge, with the clamorous exception though. Indeed, there is strongly significant evidence of a negative influence of the progressive financial liberalization on income distribution. This result is in line with the outcomes obtained by Rajan and Zingales (2003) and by Ang (2010), the last investigating the case of India in a co-integration framework.

Alternative measures of income inequality

We adopted as our main measure of income inequality the Gini index that is the most commonly-used and the most available inequality index. Nevertheless, there are numerous other possible measures that have been identified in the past literature and used in the empirical investigations.[8] One alternative is given by considering quantile shares or ratios between different quantiles of income distribution. For instance, in addition to the Gini index, Panizza (2002) applies the share of the third quantile (Q3) of the income distribution, whereas Hu and Zou (2000) study the fifth (Q5), the first (Q1), the third and fourth together (Q34) and the ratio between the fifth and the first (Q5/Q1) quantile. All are supposed to express the changing proportions of the overall income distribution of the rich (Q5), of the poor (Q1), of the middle class (Q34) and of the relative share relating to the two extreme classes (Q5/Q1). A drawback of such quantile (or also percentile) measures of income inequality is that they ignore a piece of information concerning the shares of the distribution other than those selected. Gini index, on the contrary, summarizes the information over the entire income distribution. This notwithstanding, to strengthen our previous results, we apply three alternative quantile-based measures of income inequality, namely, Q5 and the two ratios, Q5/Q1 and Q5/Q3.

Table 3 Influence of technological change on income inequality as measured by quantiles of income distribution.

	Q5	Q5/Q1	Q5/Q3
patent	-0.041	-0.012	-0.004
	(0.011)***	(0.006)*	(0.001)**
openness	-0.037	-0.028	-0.004
	(0.006)***	(0.003)***	(0.001)***
GDPcap	-0.185	-0.089	-0.016
	(0.017)***	(0.015)***	(0.002)***
investment	-0.301	-0.151	-0.031
	(0.053)***	(0.037)***	(0.007)***
gov expend	-0.247	-0.107	-0.023
	(0.034)***	(0.026)***	(0.005)***
FI	-0.929	-0.398	-0.083
	(0.241)***	(0.239)*	(0.048)*
N. obs.	97	97	97
Wald chi-sq	700***	281***	163***

Note: Dependent variable is given by alternative measures of income inequality: fifth quantile (Q5), the ration between fifth and first quantile (Q5/Q1) and between fifth and third quantile (Q5/Q3). All variables are 4-year non-overlapping averages over the period 1996-2011. All specifications have been run according to FGLS method, allowing for country-specific serial correlation and

[8] For a comprehensive review of different methods to measure inequality, see Jenkins and Van Kerm, 2008.

heteroskedasticity in residuals. Time fixed effects are included in all specifications. ***, ** and * refer to 1, 5 and 10% significance level. Standard errors are reported in parenthesis.

The results of our estimations, summarized in Table 3, confirm those obtained previously not only regarding the technological variable but also the other controls. In particular, the arrival of novelties, as measured by patents, significantly contributed to the reduction of the share of income possessed by the richest part of the population. This is very much in line with our theoretical discussion, in which we emphasized the role of the reduction in interest rates in making the distribution of income more symmetric. An analogous conclusion can be drawn from the other two columns, where we measure the relative shares of the distribution between the richest and the poorest as well as the middle income population. The increase in patents, thus, has a positive impact on the reduction of both ratios, either because the share of the richest decreases or because the share of the poorest (middle class) increases or both.

4. Conclusion

Technological change plays a central role in income distribution. Technological change is a crucial component of the dynamics of economic growth. Economic growth does not take place only via the traditional mechanisms that relates savings to capital intensity, labor productivity and wages, but also, and actually mainly via the increase of the general efficiency of economic activities. From this viewpoint, technological change magnifies and empowers the negative relationship identified by Kuznets between economic growth and income inequalities in the context of the pre-solowian theory of economic growth.

Technological change, in fact, helps increasing total factor productivity and hence labor productivity. The increase of labor productivity leads to the increase of the absolute levels of savings and, hence, to the increase of the stock of financial resources available for investments. Additional financial resources change the position of the derived demand for capital and, hence, to the reduction of interest rates. The reduction of interest rates reduces the asymmetric effects on income distribution and accelerates the relative increase of wages. Indeed, the levels of income stemming from wealth decrease and help reducing income inequalities that are further reduced by the concurrent increase of wages.

Technological change plays a crucial role in changing income distribution by means of a second and most powerful mechanism as it affects the working of market competition. The introduction of an innovation helps creating long lasting barrier to entry and limits the working of price competition. The transfer of the increased efficiency to the final consumer is delayed substantially. Innovators enjoy extra profits that accumulate and increase existing asymmetries in the wealth distribution. This is presumed to have long lasting positive effects on income inequality via the payments of interest rates. When technological change is sporadic and slow, these inequality-enhancing effects may actually counterweight the inequality-reducing effects stemming from the increase of total factor productivity already highlighted.

Under the Schumpeterian, where the creative destruction is actually working with the frequent introduction of innovations stirred by market rivalry among competitors - using new products and new processes, new organizations, new inputs and new product markets rather than prices as the basic tool to grow and to increase market shares and sales – technological change has the chance to proceed at a fast track. The quasi-rents stemming from the introduction of innovations are quickly eroded by the following innovations. The levels of quasi-rents are low. The rates of technological change on income distribution fully display their powerful effects reducing income inequalities. Consequently, the benefits of the increase of total factor productivity are quickly transferred to the final consumer. This is the undermined factor leading to the reduction of income inequalities.

Nevertheless, the proper investigation of the relationship between technological change and income inequality requires the recognition that it works both ways. Fast rates of introduction of technological innovations reduce income inequality as much as low income inequality favors the accumulation of skills and human capital and hence the quality of knowledge externalities that make it possible for firms to react in a creative way to unexpected changes in product and factor markets favoring the rates of introduction of innovations.

The empirical analysis concentrates on the first hypothesis and confirms our conjecture that technological change contributes to the reduction of income inequality.

The policy implications are quite important, innovation policies able to support the rates of introduction of innovations, together with competition policies, are the most effective tools to reduce income inequality. Innovation policy can play a central role in reducing income inequality especially in product markets where price competition is limited by barriers to entry and to imitation based upon exclusive cost advantages that draw their origin from previous technological vintages. From this viewpoint, innovation and competition policies are complementary. The support to education and training is the next crucial component. The wider is the distribution of human capital and the larger are the chances to foster the pace of technological change and to reduce income inequalities. For the same token, it becomes clear that cohesion or even fiscal policies aimed at reducing income inequality through skill-enhancing measures can become effective innovation policies.

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