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Wage inequality and labor productivity in OECD countries*

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Abstract

In a perfectly competitive labor market, the wage rate is determined by labor productivity, so that wage dispersion reflects the marginal contribution to product of the different workers. Accordingly, wage inequality cannot be treated as an independent variable in a model of productivity, and thus economists have paid little attention to this relation. This paper studies the effects of wage inequality on labor productivity. We claim that wage inequality can lead to lower effort among workers who receive lower wages and hence lead in turn to lower aggregate labor productivity because of the lower aggregate effort level. To guide the empirical analysis, we look at aggregate panel data to investigate whether there is a relationship between wage inequality and average labor productivity. We use data from the 34 OECD countries in the period 1995 to 2007, and by allowing country fixed effects, we exploit the longitudinal dimension of the data. We find that large wage inequality is associated to lower labor productivity. So the results suggest that higher levels of the Gini index of wage inequality are associated with lower labor productivity. Moreover we study the question of whether is wage inequality that causes productivity level or viceversa by assessing non-causal homogeneity in a panel Granger framework.

Keywords: Employment; dynamic panel; labor market and labor productivity; workers' effort.

JEL Codes: C23; J23; J24; J31; J41.

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1 Introduction

In a perfectly competitive labor market, the wage rate is determined by labor productivity, so that wage dispersion reflects the marginal contribution to product of the different workers. Accordingly, wage inequality cannot be treated as an independent variable in a model of productivity, and thus economists have paid little attention to this relation. In fact, the link between wage rate and labor productivity is well anchored in economic theory: higher labor productivity should increase demand for workers and result in an increase in wages as long as the labor supply curve is not perfectly elastic. There are, in effect, also theoretical models suggesting that causality between the two variables may work in the opposite direction. Akerlof (1982, [4]), for instance, argues that higher wages generate greater effort from the workers. More recently, Helpman et al. (2008, [22]) find that a greater inter-firm heterogeneity increases unemployment, as well as wage and income inequality, whereas greater worker heterogeneity has an ambiguous effects on wage inequality.

However, the literature on the impact of wage inequality on labor productivity is sparse.

Freeman and Medoff (1984, [20]) investigate the reationship for union and nonunion workers in the United States. They point out how most studies of productivity find unionized establishments more productive than otherwise comparable nonunionized ones. Although the authors do not explicitly relate this result to a (lower) level of wage inequality per se, this plausibly points towards the existence of a link between reduced levels of relative deprivation[1] and improved labor relations (i.e., worker motivation, cooperation, and discipline). For example, Takeuchi (1985, [38]) argues that in the Japanese industrial labor relations, productivity involves much collective effort on the part of a firm's workforce, so that great wage differentials should be avoided for they arouse jealousies and ill feelings (akin to relative deprivation). Reduced intrafirm wage inequality is thereby said to promote and increase workers' cooperative efforts, the training of junior workers by senior workers, on-the-job training, and greater flexibility in job assignments.

More recently, Hibbs and Locking (2000, [23]), for example, while not finding empirical support for the thesis of wage levelling within workplaces and among industries enhancing productivity, shows nevertheless that reduction of inter-industry wage differentials positively contributes to aggregate output and productivity growth.

Another strand of literature assumes that managers choose the optimal "wage structure" with regard to

[1] By relative deprivation we refer to the payment of a wage that is less than expected.

fairness and cohesiveness that maximises productivity, opening thus to the possibility that wage inequality affect “in some way” the effort of each individual worker (Akerlov and Yellen, 1988 [7], Lazear 1989 [27], and Levine 1992 [30]). In the same vein, the introduction of pay based on managerial performance seems to increase both the mean and dispersion of workers productivity, Bandiera et al. (2007, [10]).])). They also show that managers target their effort towards more able workers while the less able workers are more likely not to be selected for employment.

Thus: can wage inequality be a stimulus to work more productively? On the one hand, at the firm level, Becker (1964, [11]) suggests that greater wage inequality might reduce the incentives to invest in vocational education, hence with detrimental effects on productivity growth. According to Akerlof and Yellen (1988, [7]), Akerlof (1984, [5]) and Cohn et al. (2010, [16]) sagents feeling under-rewarded tend to supply lesser efforts, with the evidence strongly supporting this result. Also Agell and Lommerud (1993, [1]), and Moene and Wallerstein (1997, [34]), maintain that reducing pay differentials between industries and plants may enhance efficiency by speeding up the movement of labor and capital from low to highly productive activities. Moreover, “narrowing wage dispersion can increase cohesiveness, and in participatory firms cohesiveness can increase productivity” (Levine, 1991 [29]).

At the country aggregate level, Medner and Rehn (1952, [33]) argue that wage solidarity i.e. equal pay for equal works regardless of the characteristics of the firm - can increase productivity, as high wages in low productivity firms/sectors would force them to exit, and thus resources would move to higher productivity firms/sectors. Levine (1991, [29]) claims that raising low-end wages may lead to increased national output as long as the rise in labor costs balances the productivity increase due to higher cohesiveness[2].

However, Caroli and Van Reenen (2001, [14]) show that a higher pay ratio for skilled to unskilled workers has a negative effect on organizational arrangements, which in turn, have relevant shortcomings for productivity growth. According to Agell and Lommerud (1997, [2]) and Agell (1999, [3]), compressing wage distribution may also lead to fewer low skilled jobs, acting as a signal to workers to invest in human capital or else face unemployment. Thus, the introduction of a minimum wage would lead to greater human capital accumulation and higher productivity. In Moene and Wallerstein (1997, [34]) theoretical discussion, wage compression can raise profitability, increase the rate of new firm entry, and lead to a more modern capital stock (the seminal contribution is Salter's paper, 1996 [36]).

[2]At the margin, an increase in low-end wages would leave profit unchanged, while raising productivity, output, and of course welfare for the low-end of the wage distribution.

Hereafter, we test whether wage dispersion may affect labor productivity. To the best of our knowledge, there are not empirical studies testing such hypothesis using country-level data.

We use "a panel of 34 OECD countries", to ascertain whether the Gini index of wage inequality (as provided by ILO) has affected the average level of labor productivity, for the years 1995 through 2007.

We begin by presenting some motivations in a a really ad hoc and simple theoretical model to account for how changes in wage inequality affect labor productivity (section 2). Section 3 introduces data sources and some descriptive statistics. Subsections 3.1 and 3.2 present the econometric specification and results. Section 4 draws some conclusions.

2 Motivations

It is important to stress that the next theoretical model aims to motivate the empirical exercise for the next sections. In fact the aim of this section is just to illustrate how wage inequality could lead to lower measured labor productivity. The next model is really quite ad hoc since we should think that each of the types of workers are hired by distinct firms that use different technologies, and that this is why the workers are paid different wages. Although writing down the profit maximization problem, we should assume that the two labors enter within the same production function featuring decreasing returns to scale. More generally, the next theoretical model leaves for further research many questions unaddressed, for instance: i) why doesn't wage inequality lead to higher increases in effort as workers become more eager to be identified as good workers that get rewarded with the higher paying jobs? We are not suggesting that this is the way the world necessarily works, but rather that the next theoretical model simply assumes its effects and does not seek to shed any light on the economic foundations which is something for further research. One of the advantages of laying out these foundations is that it might generate useful results that would allow you to sharpen the empirical analysis. Hence, a simple theoretical model is presented that assumes that:

1. wages in each country are set exogenously by a bargaining process between representatives of workers and employers for which neither workers nor firms have any control over the wage outcome;

2. that workers are homogenous in skill and ability;

3. that wage differences arise between workers of equal skill and ability because they work in firms that have different levels of technology; and

4. that low wage (underpaid) workers will have lower productivity relative to high wage workers.

Let us assume that N is total employment, for simplicity normalized to 1, and that there is no unemployment. Workers are identical and wages are determined outside the model (e.g. through bargaining between representatives of employers and employees), so that both firms and workers consider them as given.

Let worker j be paid a wage[3] w_j that is greater than worker i's wage, $w_i < w_j$, they are positive numbers, of course. In other words, the i-worker is underpaid compared to the j-worker.

Since the wage is determined exogenously, variations in one type of worker's wage means - taking constant the other worker's salary - a variation in wage inequality.

Let us now assume that the effort function of the representative worker, say k, is:

$$e_k = \begin{cases} aw_k & \text{if } w_k \geq w_{-k} \\ aw_k + b(w_k - w_{-k}) & \text{if } w_k < w_{-k} \end{cases} \tag{1}$$

Equation (1) basically indicates that a worker k is susceptible to wage inequality only if his own wage is lower than the other's $(-k)$. As we assume that there exists only two types of workers, i and j, and that j is overpaid with respect to i, the equations for the effort the two individuals will supply, are:

$$e_i = aw_i + b(w_i - w_j) \tag{2}$$

$$e_j = aw_j \tag{3}$$

with $a > 0$, $b > 0$, $e_j \geq e_i > 1$ and, by hypothesis, $w_j \geq w_i$. Equations (2) and (3) imply that if the wage is the same between the two types of workers, they supply the same level of effort. Otherwise, the worker i supplies a lower level of effort because it is affected by wage inequality.

The unique and necessary input for production is represented by $E(e_i, e_j)$ and is a linear combination of the individual efforts (equations (2) and (3)) of the i^{th} and j^{th} workers. We imply here that the contributions

[3] We are talking of wage or wage rate indifferently, as we suppose workers working the same time shift.

to total inputs necessary for production are different between low- and high-paid workers. Such difference is not only due to differences in effort supplied, but high-paid workers contribute more to the function than those underpaid or low-paid workers.

One may wonder why identical workers may have different salaries. We justify this fact by assuming that high-paid people work for more technological and productive firms, so the effort of those people produces more input than people employed in firms which use a lower level of technology. This difference is embodied in the coefficient θ, which is assumed to be greater than one for high-paid workers (which therefore have a higher marginal productivity per unit of effort), and equal to one for the low-paid workers. The equation determining the total input necessary for production is, therefore,

$$E = qe_i + (1-q)\theta e_j \tag{4}$$

where $q \in [0,1]$ represents the fraction of i-workers who are employed over the entire workers' population, and $\theta > 1$ - as already anticipated - represents the greater contribution of high-paid workers to E due to the fact that they are employed in a more technological firm.

In our model economy, a country's labor productivity function is given by $Y/N = Y(E)$. This function $Y(E)$ is increasing (the marginal product of E is positive) and concave (diminishing returns exist in E). Labor productivity is basically total produced output (Y) over the total workers' population (N), under the full employment assumption. Of course, since total workers' population is normalized to one, labor productivity is equal to total output. The equation representing both output and labor productivity is, therefore:

$$Y = E^{\alpha} \tag{5}$$

where $\alpha \in (0,1)$. As mentioned, in our model with zero unemployment, profit-maximising firms actually choose the combination of i and j workers to hire, that is to say q.

Total profits are given by:

$$\Pi = pY - qw_i - (1-q)w_j \tag{6}$$

where $p > 0$ represents the given output price that clears markets. Hence, given p, the problem involves choosing the optimal $q \in [0,1]$ (share of i-workers to hire) for the maximization program, $\max_q \Pi(q)$. Substituting equation (5) into equation (6) we get the expression for profits expressed in terms of efforts, wages and the fraction of i-workers:

$$\Pi = p(qe_i + (1-q)\theta e_j)^\alpha - qw_i - (1-q)w_j, \tag{7}$$

which must be differentiated with respect to q to find the optimum. Thus, applying FOC, i.e. taking the first derivative of equation (7) with respect to q and rearranging, we get:

$$\frac{\partial \Pi}{\partial q} = 0 \Rightarrow \alpha p \cdot E^{\alpha-1}(e_i - \theta e_j) = w_i - w_j \tag{8}$$

which basically says that marginal revenues (left hand side of the equation) must be equal to marginal costs (right hand side). It follows, after the necessary substitutions and rearrangements,

$$q^* = \frac{1}{\eta} \cdot \left[\left(\frac{w_i - w_j}{\alpha p \eta} \right)^{\frac{1}{\alpha-1}} - \theta a w_j \right] \tag{9}$$

where:

$$\eta \equiv a(w_i - \theta w_j) + b(w_i - w_j),$$

that is the share of i-workers to hire depends on wage inequality $(w_i - w_j)$ which affects the effort functions e_i and e_j. Notice that η represents the marginal variation of E (the necessary input for production) with respect to variations of q, that is to say, $\eta = \partial E/\partial q$. This means that increasing the share of low paid workers in the employment population, the necessary input for production will decrease, if wages are kept constant.

In order for q^* to be nonnegative, the following condition must hold:

$$\left[\left(\frac{w_i - w_j}{\alpha p \eta} \right)^{\frac{1}{\alpha-1}} - \theta a w_j \right] < 0. \tag{10}$$

Equation 10 can be rewritten as

$$\underbrace{\left(\frac{\alpha pa + \alpha pb - (\theta a w_j)^{1-\alpha}}{\theta\alpha pa + \alpha pb - (\theta a w_j)^{1-\alpha}}\right)}_{\Omega} w_i - w_j > 0, \tag{11}$$

which is satisfied if and only if the following two conditions hold:

$$\theta a w_j \quad > \quad \big(\alpha p(\theta a + b)\big)^{\frac{1}{1-\alpha}}, \tag{12}$$

$$\Omega \quad > \quad \frac{w_j}{w_i}. \tag{13}$$

Remark 1. *Equation (12) says that $q*$ is nonnegative if the contribution of the single j-worker to the production of the necessary input, E, i.e. $(\theta a w_j)$ is greater than a certain parameter that involves the price of the product, p, the output elasticity, α, and the constants terms (a and b) of the worker's effort functions.*

Remark 2. *Equation (13) basically says that the ratio Ω must be greater than the ratio of the wages earned by the $j-$ and the $i - workers$. This happens when θ is sufficiently large.*

Remark 3. *Another characteristic of q^* is that it is increasing in w_j, so $\partial q^*/\partial w_j > 0$, and this indicates that given the salary of the low-paid worker, the higher is wage inequality, the greater is the demand for low-paid workers.*

Now, country's labor productivity is given by:

$$\frac{Y}{N} = Y = \quad (q^* e_i + (1 - q^*)\theta e_j)^\alpha. \tag{14}$$

Hence, it is crucial here to check what happens to the country's labor productivity when w_j increases (i.e. the level of wage inequality).

Proposition 1. *As wage inequality increases, the effect on country's labor productivity is negative.*

Proof. To prove the above statement, we simply must find that: $\frac{\partial Y}{\partial(w_i - w_j)} < 0$. Note that, substituting equation (9) into country's labor productivity and rearranging, we get:

$$Y^* = \left[\left(\frac{w_i - w_j}{\alpha p[a(w_i - \theta w_j) + b(w_i - w_j)]} \right)^{\frac{1}{\alpha - 1}} \right]^{\alpha} = \left(\frac{w_i - w_j}{\alpha p \eta} \right)^{\frac{\alpha}{\alpha - 1}}, \tag{15}$$

and then, the derivative of labor productivity with respect to inequality (wage differential) is given by:

$$\frac{\partial Y}{\partial w_j} = \frac{a \alpha w_i (\theta - 1) \left(\frac{w_i - w_j}{\alpha p \eta} \right)^{\frac{\alpha}{\alpha - 1}}}{(w_i - w_j)(\alpha - 1)\eta} < 0. \tag{16}$$

Basically, this result (equation (16)) is negative because: $\eta < 0$, $(\alpha - 1) < 0$ and $w_i - w_j < 0$. Equation (16) indicates that the greater the inequality, the greater is the negative impact on a country's labor productivity. Otherwise, when wage differentials are zero ($w_i = w_j$), labor productivity is not affected. ■

In this sense, the main motivation of this research is based on the theory of efficiency wages which implies a kind of reverse causality: rather than wages being set according to productivity, they have to be set at a particular level in order to achieve a specific productivity in a world with labor market institutions (Shapiro and Stiglitz 1984: 434). Efficiency wage models lead to an equilibrium under which wages are set at the level at which workers decide not to shirk.

In the next section, we carry on a study of empirical evidence complying with the relationship between labor productivity and wage inequality.

3 Empirical evidence and econometric model

Several factors may influence labor productivity. In the previous section, we have highlighted how one of them might be wage inequality (see **Proposition 1**). But one has to be aware of the fact that labor productivity may be affected by other variables, too. Thus, we will consider also GDP per capita, the level of employment and the total of number of hours worked as determinants of labor productivity.

The level of employment can be also responsibile for (variations in) productivity levels. Gust and Marquez (2002, [21]), for instance, identify a negative relationship between changes in the employment rate and productivity growth. Authors attribute this to the fact that a rise in the employment rate is accompanied by the arrival of less skilled workers, this negatively affecting productivity. Another reason could be that periods of high unemployment increase workers' productivity due to the stronger incentive to keep their job[4].

GDP per capita can affect productivity also because it enhances investment in both human and physical capital. Therefore, certain problems of endogeneity will have to be coped with by using instrumental variables. For instance, GDP and labor productivity may be simultaneous because, on one side, GDP per capita may induce firms to invest more in technology and, on the other side, more investments can be responsible for more economic growth[5].

Let us look at database and specification of our econometric model. It will be useful to provide the definition of our variables so that the regression of labor productivity on GDP and others variables should not be endogenous as the regressors on the right are the elements needed to build the left-hand variable. However we control for endogeneity problems.

Source of data for labor productivity (which is expressed per hour worked), GDP per capita (1990 US $) and total hours worked per capita come from the *Conference Board and Groningen Growth and Development Centre* (Total Economy Database, september 2008). Data for employment is from *World Bank*. Data on wage inequality (measured by Gini index of wage inequality) is supplied by the *International Labor Organization* (ILO, Global Wage database, 2010).

Denoting by:

1. LP - labor productivity per hour worked in 1990 US$ is defined as real output in national currency per hour worked. Although the labor productivity measure presented by The Conference Board International Labor Comparisons (ILC) program relates output to the hours worked of persons employed in manufacturing, it does not measure the specific contributions of labor as a single factor of production. Rather, it reflects the joint effects of many influences, including new technology, capital investment, capacity utilization, energy use, and managerial skills, as well as the skills and efforts of

[4]In fact, Oulton (1995, [35]) and Eltis and Higham (1995 [18]), analysing UK productivity since 1980, find that harsh recessions in the early 80's (with of course, high levels of unemployment) may have caused inefficient business to exit (rising average level of productivity) and, at firm level, the least productive workers may have been made redundant first, once again rising average productivity.

[5]To avoid such problem, lagged GDP per capita is used as instrument for its actual level. Remember that the estimators of a dynamic panel data uses internal instruments, which are defined as instruments based on previous realizations of the explanatory variables, this is in order to better consider the potential joint endogeneity of the regressors.

the workforce.

2. *Gini* - Gini index of wage inequality is Gini for wages or earnings, thus excluding income from other sources. A value of 0 corresponds to complete equality, whereas a value of 1 (or 100) refers ot complete inequality.

3. *GDP* - GDP per capita in 1990 US$ is GDP per capita in 1990 US$ (converted at Geary Khamis PPPs), the values are obtained as the overall real GDP divided by total population for each country.

4. *H* - annual hours worked per worker is measured by hours actually worked per person employed per year.

5. *E* - total population employed over total population is measured by total population employed over total population, age 15+.

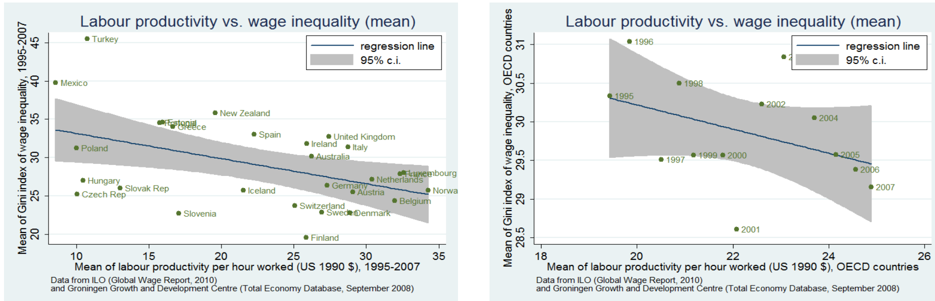
Table 1 introduces the main summary statistics of the variables we are using (median, standard deviation, minimum and maximum, for each of the enumerated variables.)

Table 1: Summary statistics of the main variables

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
$Year$	-	-	1995	2007	442
LP	22.21	8.08	7.44	37.65	429
$Gini$	29.79	6.11	18.9	46	254
GDP	17,617	6,538	5,623	39,976	442
H	1,778	216	1,398	2,497	429
E	55.26	6.89	38.9	75.10	442

In our panel of 34 OECD countries, plotting the mean of wage inequality (represented by Gini index) over labor productivity, we observe a tendency to have higher productivity levels associated to lower wage inequalities, and this can be seen through time as well as across countries:

Figure 1. Relations between Wage Inequality and Labor Productivity.



Dots in the graph indicate each country's position in the inequality - productivity relationship.

Figure 1 is a graphical representation of the statement in our main Proposition 1 (equations 13-14) and, on the left hand side, it shows that a cross country regression of labor productivity over Gini index of wage inequality would predit a negative coefficient, indicating that a positive variation of wage inequality is associated with a negative variation in labor productivity. On the right hand side of the figure, we have a similar picture, though there the mean of wage inequality and labor productivity is calculated over years, and not across countries. From 1995 to 2007, we indeed witness an average decrease in wage inequality and an increase in labor productivity, a facto even more evident for the years 2004 through 2007. Hence, Figure 1 clearly shows that this time period has been characterised by an economic expansion (increase in productivity) and a decline in wage inequality.

3.1 About causality

To address the question of whether is wage inequality that causes productivity level or viceversa, we use a recently developed methodology for assessing non-causal homogeneity in a panel Granger framework based on with the procedure developed by Dumitrescu and Hurlin (2012, [17]).

Causality tests with panel data are perfomed –similarly to what happens in time-series data– by regressing k lagged values of the dependent variable y for k=*1,...,K* and k lagged values of another independent variable x (for k=*1,...,K*). If one or more of the lagged values of x are significant, we are able to reject the null hypothesis that x does not Granger cause y. In panel frameworks, however, employing the conventional Granger tests raises two important inferential issues, both dealing with the potential heterogeneity of the individual cross-section units. The first is the possibility of distinctive intercepts across individual cross-section units, a problem that may be easily solved by means of fixed effect models. The second and more problematic issue concerns the possibile differential causal relations across units. In more practical terms, the fact that causality goes in a certain given direction for one country does not imply that the direction need be the same (with equal coefficients) for all countries in the sample, an assumption older tests of causality for panel data relied on Holtz-Eaking et al. (1988, [24]).

Dumitrescu and Hurlin's (2012, [17]) simple test of homogeneous non causality assumes, under the null, that there is no causal relationship for any of the units of the panel and considers a heterogeneous panel data model with fixed coefficients (in time). It also specifies the alternative hypothesis as heterogeneous causality, which assumes that there is a causal relationship from x to y for a subgroup of individuals only (possibly, all). The statistics proposed is based upon averaging standard individual Wald statistics of Granger non causality tests (as used in first generation panel unit root tests), under the assumption of cross-section independence is shown to converge sequentially in distribution to a standard normal variate when the time dimension T tends to infinity, followed by the individual dimension N. In case of T and N both fixed, we also get critical values generated through simulations of the semi-asymptotic distribution of the average statistics. Let us consider x and y two stationary variables. For each individual $i = 1, ..., N$ at time $t = 1, ..., T$, the authors consider the following linear model:

$$y_{i,t} = \alpha_i + \sum_{k=1}^{K} \gamma^{(k)} y_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(k)} x_{i,t-k} + \epsilon_{i,t} \tag{17}$$

with the number of lags is denoted by $K \in \mathbb{N}$ and $\beta_i = (\beta_i^{(1)}, ..., \beta_i^{(K)})'$. For simplicity, the individual effects α_i are supposed to be fixed in the time dimension, and the initial conditions $(y_{i,-K}, ..., y_{i,0})$ and $(x_{i,-K}, ..., x_{i,0})$ of both individual processes $y_{i,t}$ and $x_{i,t}$ are given and observable. The lag orders K are assumed to be identical for all cross-section units, but the authors allow the autoregressive parameters $\gamma_i^{(k)}$ and the regression coefficient slopes $\beta_i^{(k)}$ to differ across groups (but are kept constant through time).

Under the following assumptions: (1) normality and identically distributed across groups of individual residuals and (2) both individual variables $x_i = (x_{i,1}, ..., x_{i,T})'$ and $y_i = (y_{i,1}, ..., y_{i,T})'$ are covariance stationary with finite variance, the average statistics $W_{N,T}$ associated with the null of homogeneous non causality hypothesis is defined as

$$W_{N,T} = \frac{1}{N} \sum_{i=1}^{N} W_{i,T} \tag{18}$$

and asymptotically, for T first and then N tending to infinity, the following distribution approaches to a standard normal.

$$Z_{N,T} = \sqrt{\frac{N}{2K}}(W_{N,T} - K) \xrightarrow{d} N(0,1) \tag{19}$$

Equation (18) represents a simple average of the individual Wald statistics $W_{i,T}$ for the i^{th} cross-section unit corresponding to the individual test $H_0 : \beta_i = 0$. This individual Wald statistics $W_{i,T}$ follows a χ^2 distribution with K degrees of freedom as $T \to \infty$. Equation (19) follows from the assumption of independent distribution across groups of individual residuals. This allows the individual $W_{i,T}$ statistics for $i = 1, ..., N$ to be identically and independently distributed with finite second order moments as $T \to \infty$, and therefore, by Lindber-Levy central limit theorem under the homogeneous non causality hypothesis, the average statistic $W_{N,T}$ sequentially converges in distribution.

For large N and T samples, if the realization of the standardized statistic $Z_{N,T}$ is higher than the corresponding normal critical value for a given level of risk, the homogeneous non causality hypothesis is rejected.

In practical terms, however, when we deal with real data we always face fixed T and fixed N distributions. Dumitrescu and Hurlin (2012, [17]) computed the exact empirical critical values for the corresponding sizes N and T via stochastic simulations. These critical values must be compared with the mean Wald statistic $W_{N,T}$ defined in equation (18), and if the value of $W_{N,T}$ comes out to be greater than the simulated critical value, the null of homogeneous causality is rejected. Here we do not report the table of the simulated critical values since the reader can easily refer to their original publication.

In the following, we discuss our procedure to determine the direction of causality.

$H0_1$**: Wage inequality does not homogeneously cause variations in labor productivity.**

We then proceed to the estimation of the single Wald statistics for each unit in our sample. For each of our 34 OECD countries, we estimate two models, the first (unrestricted) in which two lagged values of the dependent variable "labor productivity per hour worked" and two lagged values of Gini index of wage inequality are regressed over the current value of labor productivity per hour worked and we store the sum of squared residuals (SSR_u) of the regression. We then estimate another model, restricted, model, where the β_i coefficients attached to the lagged values of Gini index are bounded to zero (or –alternatively– excluded from the model) and, again, we store the sum of squared residuals (SSR_r) of the regression. The individual Wald statistics are computed according to the following formula:

$$W_{i,T} = \frac{(SSR_r - SSR_u)/K}{SSR_u/(T - 2K - 1)} \tag{20}$$

and then they are averaged trough all the units availabe.

Result 1. *The statistics $W_{N,T}$, computed according equation (18), displays a value of 4.22, which is greater than the simulated critical value of 2.68 (this critical value assumes 15 units and 10 observation for each unit), and then $H0_1$ is rejected. This means that the index of wage inequality causes variations in labor productivity for at least one (and possibily more) country in the sample.*

$H0_2$**: Labor productivity does not homogeneously cause variations in wage inequality.**

Similarly, we proceed to the estimation of the single Wald statistics for each unit in our sample. For each of our 34 OECD countries, we estimate two models described above.

Result 2. *The statistics $W_{N,T}$, computed according equation 18, displays a value of 5.53, which is greater than the simulated critical value of 2.68 (this critical value assumes 15 units and 10 observation for each unit), and then $H0_2$ is rejected. This means that also labor productivity causes variations in the distribution of wages for at least one (and possibily more) countries in the sample.*

3.2 Econometric specification and results

Herefter we are using Arellano-Bond (1991) estimator. This procedure is appropriate –by estimating the model in first differences– to account for individual, time invariant effects, and it is based on the method known as Generalized Method of Moments (GMM) in first differences. First differences are calculated from the equation in order to remove observed and permanent individual heterogeneity. Subsequently, lagged levels of the series are used as instruments for the endogenous variables in first differences. That is, the estimators of dynamic panel data use internal instruments, defined as instruments based on previous realizations of the explanatory variables, to better treat the potential problem of joint endogeneity of the regressors. In sum, Arellano-Bond GMM estimator introduces dynamic effects into the standard model of panel data by including a lag of the dependent variable on the right hand side, while correcting the endogeneity problem, fixed effects, short time span and possible autocorrelation.

The equation to estimate is, accordingly:

$$
\begin{aligned}
\Delta LP_{i,t} &= \beta_0 + \beta_1 \Delta LP_{i,t-1} + \beta_2 \Delta GDP_{i,t} + \beta_3 \Delta GDP_{i,t-1} \\
&+ \beta_4 \Delta H_{i,t} + \beta_5 \Delta H_{i,t-1} + \beta_6 \Delta E_{i,t} \\
&+ \beta_7 \Delta E_{i,t-1} + \beta_8 \Delta Gini_{i,t} + \Delta u_{i,t} \qquad (21)
\end{aligned}
$$

$$\Delta u_{i,t} = \Delta v_{i,t} + \Delta e_{i,t}. \qquad (22)$$

where the subscripts $i = 1, ..., N$; $t = (1, ..., T)$ indicate the number of observations and the period of time, and $u_{i,t}$ is the random error of the model containing fixed effects (like country-specific effects) decomposed into unobservable, $\Delta v_{i,t}$, and omitted observable effects, $\Delta e_{i,t}$. By first differencing, the fixed effect is removed, because it does not vary with time.

Table 2 shows the coefficients resulting from the estimation of equation (21).

Result 3. *Our estimation indicates that:*

1. *While controling for endogeneity, all the coefficients are statistically significant, and the resulting standard errors are consistent with panel-specific autocorrelation and heteroskedasticity in one-step estimation.*

2. *Wage inequality measured by Gini index has a negative coefficient indicating that it has a negative effect "ceteris paribus" on country's labor productivity. That is, more wage inequality implies less labor productivity. This result indicates that, for the period studied, inequality affects labor productivity. Hence, the economic policy says that in order to increase productivity, inequality should decrease.*

3. $\Delta GDP_{i,t}$ *is significant at 5% level, indicating that income increases labor productivity as it allows to save and invest more in new technologies which in turn allow workers to work faster and more efficiently. Differenced lagged GDP is however negative, indicating a decreasing rate of productivity growth (although positive).*

Table 2: Regression coefficients

	(1)
	$\Delta LP_{i,t}$
$\Delta LP_{i,t-1}$	0.775***
	(11.54)
$\Delta GDP_{i,t}$	0.00112***
	(10.96)
$\Delta GDP_{i,t-1}$	-0.000926***
	(-7.03)
$\Delta H_{i,t}$	-0.0113***
	(-10.20)
$\Delta H_{i,t-1}$	0.00581***
	(4.67)
$\Delta E_{i,t}$	-0.319***
	(-7.95)
$\Delta E_{i,t-1}$	0.216***
	(5.14)
$\Delta Gini_{i,t}$	-0.0305*
	(-1.97)
N	172

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Estimations are corrected by heteroskedasticity through the White method.

4. *Percapita hours worked have a negative impact on labor productivity, as it is highlighted by the coefficient attached to* $\Delta H_{i,t}$ *in table 2. This effect is probably due to the fact that the level of attention and performance decreases as the individual gets tired and tired. This variable lagged one period, however, shows that there exists a sort of "learning process" through which the same worker gets used to work hard, increasing in the long period his level of productivity. An alternative interpretation is simply that, percapita hours' effect is not immediate on labor productivity (although lag is positive), because as in any process, when you start a job initially invested time tends to reduce labor productivity (and that in the beginning still not harvested results), however, after some time the impact becomes positive (when these working hours begin to yield results).*

5. *Employment ratio has a negative effect on labor productivity because high unemployment makes outside opportunities of work less frequent and therefore workers who have a job tend to work more in order to lower the probability to get fired. The lagged differenced employment ratio has however a positive effect, indicating that although employment ratio decreases labour productivity, it does at an increasing rate.*

Our test of homogeneous non-causality, however, is not able to accept the null that Gini index does not homogeneouly cause labor productivity, nor that the latter does homogeneously cause wage inequality. This means that wage inequality does cause labor productivity in at least one country and, on the other hand, labor productivity may cause wage inequality in at least one country, too. For this reason, we also specify an equation for Gini index of wage inequality and estimate it.

$$\begin{aligned} \Delta Gini_{i,t} &= \beta_0 + \beta_1 \Delta LP_{i,t-1} + \beta_2 \Delta GDP_{i,t} + \beta_3 \Delta GDP_{i,t-1} \\ &+ \beta_4 \Delta H_{i,t} + \beta_5 \Delta H_{i,t-1} + \beta_6 \Delta E_{i,t} \\ &+ \beta_7 \Delta E_{i,t-1} + \beta_8 \Delta LP_{i,t} + \Delta u_{i,t} \end{aligned} \tag{23}$$

$$\Delta u_{i,t} = \Delta v_{i,t} + \Delta e_{i,t}. \tag{24}$$

Table 3 presents the corresponding empirical results, where –as pointed out by equation (23).

Table 3: Regression coefficients

	(1)
	$\Delta Gini_{i,t}$
$\Delta Gini_{i,t-1}$	0.131
	(1.41)
$\Delta GDP_{i,t}$	-0.000988
	(-1.27)
$\Delta GDP_{i,t-1}$	0.000658
	(0.95)
$\Delta H_{i,t}$	0.00197
	(0.22)
$\Delta H_{i,t-1}$	-0.000261
	(-0.05)
$\Delta E_{i,t}$	-0.166
	(-0.64)
$\Delta E_{i,t-1}$	-0.164
	(-0.69)
$\Delta LP_{i,t}$	0.581
	(1.63)
N	147

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Result 4. *Treated wage inequality as a dependent variable, while labour productivity appears among the regressors. It should be noticed that all the coefficients are not statistically significant.*

Remark 4. *Our results are consistent with the view that, in order to maintain high productivity, OECD countries must be concerned with the social legitimacy of their wage structure by reducing wage inequality.*

4 Concluding remarks

In this paper, rationalizing with the aid of a simple theoretical model, we have shown that wage inequality has a negative effect on country's labor productivity. Then, we have proceeded to study an econometric model in order to analyze the effects of wage inequality on labor productivity for a panel of 34 OECD countries through 1995-2007. Using Arellano-Bond GMM estimator for dynamic panel data models, we have found that wage inequality (expressed by Gini index) does affect negatively labor productivity.

The reason we believe that drives such result is that wage inequality induces workers believing their wage to be unfair, to supply less effort. This is consistent with the view of Akerlof and Yellen (1986 [6]), Akerlof (1984, [5]) and Cohn, Fehr and Gotte (2010, [16]) who find that pay increases up to a fair level do lead to higher work effort. When wage inequality is high, it is also more likely that people receiving a low wage believe it to be unfair, so that an increase in wage inequality (i.e. a decrease of already low wages or an increase in high wages) is associated with a reduction of lower paid workers' effort. According to Cohn et al., pay raises above the fair wage are not associated to corresponding increases in effort, and the reduction of wage inequality in this sample of OECD countries must be one reason why the global level of productivity has increased. Our simple model suggests that, even though a pay increment increases effort proportionally, under decreasing returns to scale, labor productivity as measured by output per unit of effort may decline too.

Further research indicates that one should find a variable capturing the effect of market integration which could have significant effect of wage inequality. Financial or commercial openness of the countries could help to capture the differences in labor productivity directly and indirectly through wage differential. Theoretically speaking, higher capital mobility (FDI) could have an (at least ambiguous) impact on wage inequality. Do level of FDI matter here?

Another possible way of purging out the effect of wage differential on labor productivity which is not captured otherwise could be to include the share of GDP brought to the economy by some sectors which are suspected to contain and increase disparities in wages. For example, one of the sectors which has been a major cause for wage differential is the growth of information technology (IT). In this regard also policy regulations in OECD economies could be a reason for the wage dispersion. OECD economies have undergone lots of regulatory reforms like relaxing anti-competitive product market regulations and employment protection.

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