On Skill Heterogeneity and Inflation

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Abstract
This paper examines the welfare costs of inflation within a dynamic general equilibrium framework that incorporates ex ante skill heterogeneity among workers. Money is introduced via a cash-in-advance constraint on the purchases of consumption. Numerical experiments based on a plausible parameterization of the model indicate that welfare costs of inflation relative to an optimal monetary policy decrease as skill heterogeneity increases. An implication of this feature is that a greater degree of skill heterogeneity would be associated with a greater tolerance for inflation, consequently implying a positive correlation between agent heterogeneity and inflation. We also conduct an empirical study based on a panel of several countries that lends some support to this hypothesis. If we focus on the experience of industrialized economies, the data finds supports a positive inflation-heterogeneity correlation. However, this is not true of less developed economies, in which the inflation heterogeneity correlation if found to be negative.
1. Introduction

The impact of income inequality on the aggregate outcomes of an economy is central to a large and growing body of literature, and remains an open area of research. In many of the theoretical studies that analyze the link between inequality and growth, the role of human capital inequality has been strongly emphasized as being an important determinant of income inequality. See for example, Glomm and Ravikumar (1992), Saint-Paul and Verdier (1993), Galor and Tsiddon (1997), Chakraborty and Das (2003) among others. At the empirical level, lack of suitable data has often led researchers to focus on the effect of income inequality on growth. This shift in focus would not be too much of a problem if, as in some of the contributions to the literature, we implicitly assume that income inequality is a good proxy for human capital inequality. However, recent evidence suggests that income and human capital distribution statistics can show very low correlations (Castello and Domenech, 2002). In addition, Castello and Domenech (2002) also find that human capital inequality measures provide more robust results than income equality measures in the estimation of standard growth and investment equations.

Parallel to developments in the inequality-growth literature, there have been strands of literature that focus on the costs of inflation in the presence of income inequality. Studies based on a political economy perspective of the inflation-income heterogeneity link provide a theoretical rationale for a positive as well as a negative correlation between the two aggregates. Dolmas, Huffman and Wynne (2000), document a positive correlation between income inequality and inflation, which is rationalized by a theory of the determination of inflation outcomes in democratic societies that illustrates how greater inequality leads to greater inflation, owing to a desire by voters for wealth redistribution. Bhattacharya, Bunzel and Haslag (2003), on the other hand, present a theory and empirical evidence that supports a non-monotonic relationship between inequality and inflation. The non-monotonic relationship is rationalized by the ability of some agents to hedge against inflation by holding interest bearing assets. Albanesi (2000) analyzes a model in which the poor are more vulnerable to inflation, and are the weaker party in the political process that determines inflation, leading to a positive inequality-inflation correlation.
Given the links between human capital and wealth inequality emphasized in some of the literature cited above, it is of interest to examine the relationship between human capital heterogeneity and inflation. Using a new data set on human capital heterogeneity in a large panel of countries, created by Castello and Domenech (2002) this paper considers the effect of the degree of skill-heterogeneity among workers on the welfare costs of inflation. We address this issue in the framework of an equilibrium model with ex-ante heterogeneity of the type studied in Kydland (1984) and Prasad (1996), with money introduced via a cash-in-advance constraint on the purchases on consumption.

Our results are based on numerical computations based on a plausible parameterization of the model. Furthermore, we examine whether the implications of our model are consistent with the inflation experiences of a large panel countries between 1960 and 1989. We find that the theoretical implications of our model are consistent with the empirical evidence on inflation and human capital heterogeneity in a sub-sample of developed countries. Since the model economy we study in this paper, and its parameterization, is representative of developed economies, we interpret the results as supportive of the theoretical implications of the model.

Specifically, the model of this paper suggests that the welfare cost of inflation decreases as skill heterogeneity increases. Aggregate work effort in this model is positively related to the level of productivity of skilled workers. As the productivity of skilled labor, (and consequently the skill differential) increases, output and consumption increase as a result of the increase in aggregate work effort. As the heterogeneity in the model is of the ex-ante type, one may interpret this result to be supportive of the hypothesis that benefits of progress trickle down to the poor in the presence of an equity-efficiency trade-off. Welfare costs of inflation, relative to an optimal monetary policy, could therefore be potentially lower in the presence of greater heterogeneity. Empirical studies of impact of wage-inequality on work effort, such as that of Freeman and Bell (2000), do in fact imply a positive relationship between wage-inequality and hours worked.

One can also interpret this result as follows: If increasing the degree of heterogeneity leads to lower welfare costs of inflation, one may infer that economies with greater heterogeneity are likely to be more tolerant of inflation. There is some evidence that
points toward a positive correlation between inflation and human capital or skill heterogeneity. For example, Easterly and Fischer (2001), using polling data for 31869 households in 38 countries, find that the likelihood of citing inflation as a concern is inversely related to educational attainment. Also, Mulligan and Sala-i-Martin (1996) estimate the cost of adopting a financial technology that hedges against inflation, and find it to be inversely related to educational attainment. A priori, then, one may expect lower welfare costs associated with inflation in economies with greater heterogeneity, and consequently a positive human capital inequality-inflation correlation.

At the theoretical level, the issue of welfare costs associated with anticipated inflation however remains a controversial one. Economic models in which monetary policy can affect the economy’s long run growth rate yield different magnitudes of costs associated with inflation, depending on the framework in question. In recent years there have been several studies that point towards relatively small welfare costs of inflation\(^1\). An extension of the cash-in-advance framework to allow for endogenous growth, as in Gomme (1993), is shown to further reduce the welfare costs of inflation. This further serves to motivate studies of models with some form of human capital heterogeneity and its implications for the costs of inflation\(^2\).

The remainder of the paper is organized as follows. In Section 2 we describe the economic environment, and in Section 3 we briefly analyze the steady state. The model is parameterized in Section 4, in which we also find welfare costs of inflation associated with different levels of skill heterogeneity. The key implication of the quantitative experiments conducted in Section 4 is that welfare costs of inflation are inversely related to the degree of heterogeneity. In Section 5 we test this implication using a panel of a number of countries. If we focus on the experience of industrialized economies, which,

\(^1\) Cooley and Hansen (1989) compute welfare costs relative to an optimal monetary policy in a stochastic optimal growth model in which money enters due to the presence of cash-in-advance constraint on consumption purchases. Welfare costs arise due to an inflation tax – agents substitute out of the “cash-good”, consumption, towards leisure, causing a decline in work effort and consequently output. The welfare costs associated with a 10% inflation rate are reported to be about .4% of income, which is similar to the .8% and .5% figures calculated by Fischer (1981) and Lucas (1981), who compute welfare costs using the triangle under the money demand curve.

\(^2\) In Imrohoroglu (1992), however, the welfare costs of inflation in an economy in which heterogeneous agents hold money in order to smooth consumption in the face of uninsurable idiosyncratic income risk are computed to be much larger. Heterogeneity in this case is in ex-post wealth following a shock to the agent’s income, and inflation hinders the agent’s ability to smooth consumption over time.
as mentioned above, we believe our model to be more representative of, the data finds supports a positive inflation-heterogeneity correlation. However, this is not true of less developed economies, in which the inflation heterogeneity correlation if found to be negative. Section 6 concludes.

2. The Economic Environment

The economy is populated with a continuum of identical, infinitely lived households that are uniformly distributed along the unit interval [0, 1]. Each household consists of two types of workers, skilled (type 1) and unskilled (type 2). Household preferences are given by

$$E \sum_{i=0}^{\infty} \beta^i u(c_i, 1-n_{1i}, 1-n_{2i})$$  \hfill (1)

where $c_i$ represents household consumption and $n_{it}$ represents labor effort at time $t$ of type $i$ agent, $i=1, 2$. The functional form used for the momentary utility function is of the “indivisible labor” form as in Hansen (1985) and is given by

$$\log c_t - \psi a n_{1t} - (1-\psi) a n_{2t}$$  \hfill (2)

where $\psi$ and $1-\psi$ are the underlying weights assigned to the leisure of skilled and unskilled workers respectively.

Households enter period $t$ with nominal money balances $m_{t-1}$, carried over from the previous period. The government augments these money balances by a lump-sum transfer equal to the increase in money supply, where the aggregate money supply $M_t$ is determined according the following rule:

$$M_t = g_t M_{t-1}.$$  \hfill (3)

Thus the total amount of money balances held by a household at the beginning of period $t$ is the amount

$$m_{t-1} + (g_t - 1) M_{t-1}.$$  \hfill (4)

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3 Specifically skilled and unskilled workers can work some positive number $h<1$ or not at all, implying household consumption sets are non-convex. However, as in Hansen (1985) and Rogersen (1988), the household consumption set is convexified by allowing agents to trade employment lotteries. As in Prasad (1996), this economy has two independent employment lotteries, one for skilled workers and another for unskilled workers. The expected utility of each household is then defined over total household consumption and the probability of employment of each type of worker.
There is a cash in advance constraint on the purchase of the non-storable consumption good, which ensures that money will be valued in equilibrium. Expenditure on the consumption good therefore cannot exceed the total money balances available to the household, i.e.

\[ p_t c_t \leq m_{t-1} + (g_t - 1)M_{t-1}. \]  

(5)

The growth rate of money \( g_t \) evolves according to:

\[
\log(g_{t+1}) = \alpha \log(g_t) + \xi_{t+1}.
\]

(6)

\( \xi_{t+1} \) is \( i.i.d \) normal with mean \((1-\alpha)\log(\bar{g})\) and variance \(\sigma^2_\xi\), and \(\log(\bar{g})\) represents the unconditional mean of \(\log(g_t)\).

In every period \( t \), household expenditures consist of consumption \((c_t)\), investment \((x_t)\), and the amount of money balances \((\frac{m_t}{p_t})\) that are to be carried over to the next period. These expenditures must not exceed total household income, which the sum of income is earned from skilled and unskilled labor, capital, money balances carried over from the previous period, and the lump-sum monetary transfer from the government. Households therefore maximize expected lifetime utility subject to (5) and a sequence of budget constraints of the following form:

\[
c_t + x_t + \frac{m_t}{p_t} \leq w_1 n_{1t} + w_2 n_{2t} + r_t k_t + \frac{m_{t-1} + (g_t - 1)M_{t-1}}{p_t},
\]

(7)

where household investment expenditure in period-\( t \) is given by

\[ x_t = k_{t+1} - (1 - \delta)k_t. \]

(8)

In equation (8) \( k_t \) is the household’s capital stock in period-\( t \) and \( \delta \) is the rate at which the capital stock depreciates.

There is a representative firm, which hires labor \( N \) and capital \( K \) to produce output using technology of the form

\[
Y_t = e^{z_t} K_t^\theta N_t^{1-\theta}
\]

(10)

where \( z_t \) is an exogenous productivity shock, and the aggregate time \( t \) labor input is a CES function of skilled and unskilled labor, given by

\[
N_t = \left\{ \omega N_{1t}^{1-v} + N_{2t}^{1-v} \right\}^\frac{1}{1-v}.
\]

(11)
The parameter $\omega > 1$ captures the higher productivity of skilled labor\(^4\), and elasticity of substitution between the two types of labor is given by $\frac{1}{\nu}$. The exogenous productivity shock follows an autoregressive process of the form

$$z_{t+1} = \rho z_t + \epsilon_{t+1}, \quad 0 < \rho < 1,$$

where $\epsilon_{t+1}$ is i.i.d with zero mean and constant variance $\sigma^2_{\epsilon}$. The firm maximizes profits, which are equal to $Y_t - w_{1t}N_{1t} - w_{2t}N_{2t} - r_tK_t$. The optimality conditions for the firm’s problem yield the following functions for the skilled and unskilled wage rates, and the rental rate for capital\(^5\):

$$w_{1t}(z_t, K_t, N_{1t}, N_{2t}) = \frac{(1-\theta)\omega N_{1t}^{1-\nu} Y_t}{\omega N_{1t}^{1-\nu} + N_{2t}^{1-\nu}}$$

$$w_{2t}(z_t, K_t, N_{1t}, N_{2t}) = \frac{(1-\theta)\omega N_{2t}^{1-\nu} Y_t}{\omega N_{1t}^{1-\nu} + N_{2t}^{1-\nu}}$$

$$r_t(z_t, K_t, N_{1t}, N_{2t}) = \theta e^{\nu r_t} \left( \frac{K_t}{N_t} \right)^{\theta-1}.$$

For a value of $g$ greater than one, both $M_t$ and $p_t$ will grow without bound. In order to make the household’s problem stationary, some of the variables need to be transformed. To that end, we define $\hat{m}_t = \frac{m_t}{M_t}$ and $\hat{p}_t = \frac{p_t}{M_t}$. We can then state the household’s problem as follows:

$$\max \ E \sum_{t=0}^{\infty} \beta^t \left\{ \log(c_t) - \psi a_n_{1t} - (1-\psi)a_n_{2t} \right\}$$

subject to

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\(^4\) Capital letters denote aggregate economy wide per capita variables which an individual household regards as being outside its sphere of influence, while lower case letters denote variables specific to the household.

\(^5\) Since the aggregate production technology is of the Cobb-Douglas form, profits will be zero in equilibrium, even though aggregate labor effort is a CES function of skilled and unskilled labor. This is easily verified by substituting the optimal wage and rental rates in the profit function.
\[
\hat{m}_t + c_t + k_{t+1} - (1 - \delta)k_t = w_{t1}n_{t1} + w_{t2}n_{t2} + r_tk_t + \frac{\hat{m}_{t-1} + g_t - 1}{\hat{p}_tg_t}, \quad (17)
\]
\[
c_t = \frac{\hat{m}_{t-1} + g_t - 1}{\hat{p}_tg_t} \quad (18)
\]

the process for technology and monetary shocks, the aggregate capital accumulation rule, given by,
\[
z_{t+1} = \rho z_t + \varepsilon_{t+1}, \quad (19)
\]
\[
\log(g_{t+1}) = a\log(g_t) + \zeta_{t+1}, \quad (20)
\]
\[
K_{t+1} = (1 - \delta)K_t + X_t, \quad (21)
\]
as well as the economy-wide aggregate decision rules perceived by the households:
\[
N_t = N(z_t, g_t, K_t),
\]
\[
X_t = X(z_t, g_t, K_t),
\]
and,
\[
\hat{P}_t = \hat{P}_t(z_t, g_t, K_t). \quad (22)
\]

In equilibrium, aggregate per capita quantities turn out to be equal to the choices of the representative household. In particular, it must be the case that \( n_t = N_t, \ k_t = K_t, \ x_t = X_t, \) and \( \hat{m}_{t-1} = \hat{m}_t = 1. \) Since the cash in advance constraint is assumed to be binding in equilibrium, we also have \( c_t = \frac{1}{\hat{P}_t}. \)

3. The Steady State

In the non-stochastic steady state, the first order conditions with respect to \( c_t, n_{t1}, n_{t2}, k_{t1}, \hat{m}_t, \) and equilibrium conditions for this economy imply:
\[
\frac{1}{C} = \lambda_1 + \lambda_2 \quad (23)
\]
\[
\psi a = \frac{(1 - \theta)\omega \lambda_1 K^\theta N_1^{1-\theta} N_1^{-\psi}}{\omega N_1^{1-\psi} + N_2^{1-\psi}} \quad (24)
\]
\[
(1 - \psi) a = \frac{(1 - \theta)\lambda_1 K^\theta N_1^{1-\theta} N_2^{-\psi}}{\omega N_1^{1-\psi} + N_2^{1-\psi}} \quad (25)
\]
\[ \left( \frac{K}{N} \right)^{\theta-1} = \frac{1}{\beta} - 1 + \delta \quad (26) \]

\[ \lambda_1 = \frac{\beta(\lambda_1 + \lambda_2)}{g} \quad (27) \]

\[ C + \delta K = K^\theta N^{1-\theta} \quad (28) \]

Here \( \lambda_1 \) and \( \lambda_2 \) are the Lagrangian multipliers associated with the household budget and cash-in-advance constraints respectively. From equation (26), which is the equilibrium version of the first order condition for capital, it is clear that the capital to “aggregate labor” ratio is independent of inflation, and is given by:

\[ \kappa = \frac{K}{N} = \left[ \frac{1}{\theta} \left\{ \frac{1}{\beta} - 1 + \delta \right\} \right]^{\frac{1}{\theta-1}}. \]

However, as is typical in models with a cash-in-advance constraint on consumption purchases, consumption, and work effort – in this case of both skilled and unskilled type, will be negatively related to the rate of growth of money. Also for a given capital labor ratio, lower aggregate work effort implies a lower steady state capital stock. Indeed, some manipulation of the optimality conditions above yields the following expressions for consumption, skilled, unskilled and aggregate work effort, and capital:

\[ C = \frac{\omega \beta (1 - \theta) \kappa^\theta \left[ \omega + \left( \frac{\psi}{(1 - \psi) \omega} \right)^{\frac{1}{1-\nu}} \right]^{\frac{\nu}{1-\nu}}}{\psi ag} \quad (29) \]

\[ N_1 = \frac{\omega \beta (1 - \theta) \kappa^\theta}{\psi ag (\kappa^\theta - \delta \kappa) \left[ \omega + \left( \frac{\psi}{(1 - \psi) \omega} \right)^{\frac{1}{1-\nu}} \right]} \quad (30) \]

\[ N_2 = \left( \frac{\psi}{(1 - \psi) \omega} \right)^{\frac{1}{1-\nu}} \left\{ \frac{\omega \beta (1 - \theta) \kappa^\theta}{\psi ag (\kappa^\theta - \delta \kappa) \left[ \omega + \left( \frac{\psi}{(1 - \psi) \omega} \right)^{\frac{1}{1-\nu}} \right]} \right\} \]

\[ \quad \times \left\{ \frac{\omega \beta (1 - \theta) \kappa^\theta}{\psi ag (\kappa^\theta - \delta \kappa) \left[ \omega + \left( \frac{\psi}{(1 - \psi) \omega} \right)^{\frac{1}{1-\nu}} \right]} \right\} \quad (31) \]
The intuition for the negative impact of inflation on economic aggregates is straightforward, and common to several cash-in-advance models in the literature. Inflation acts as a tax on consumption since it requires the use of cash. This leads economic agents to substitute consumption for activities that do not require the use of cash, such as leisure. The decline in work effort causes a decline in output, and consequently consumption, investment and the capital stock. However, it is clear that the magnitude of the negative response to inflation in this economy is likely to be affected significantly by the parameters \( \omega, \psi, \) and \( \nu, \) which can be said to represent the extent of ex ante heterogeneity in this economy. It is then natural to expect that welfare costs computations relative to an optimal monetary policy may yield significantly different results\(^6\). While it may be somewhat inappropriate to compare levels of welfare costs in economies with or without skill heterogeneity, it is certainly interesting to examine how varying these parameters affects welfare costs. Given the relative intractability of our model, we are not able to derive any analytically meaningful results. In the next section, we therefore derive some conclusions regarding welfare costs based on numerical experiments using a plausibly parameterized version of the model.

4. Inflation and Agents’ Heterogeneity: Results Based on Quantitative Experiments
In this section, we explore the relationship between inflation and heterogeneity, by examining how welfare costs change as we vary the levels of the parameters that capture

\[ N = \frac{\omega + \left( \frac{\psi}{(1-\psi)\omega} \right)^{\frac{1-\nu}{\nu}}}{\psi \omega (\kappa^\theta - \delta \kappa)^{\frac{1}{\nu}}} \omega \beta(1-\theta) \kappa^\theta \]  

(32)

\[ K = \frac{\omega + \left( \frac{\psi}{(1-\psi)\omega} \right)^{\frac{1-\nu}{\nu}}}{\psi \omega (\kappa^\theta - \delta \kappa)^{\frac{1}{\nu}}} \omega \beta(1-\theta) \kappa^{1+\theta} \]  

(33)

\(^6\) It is easy to check that the optimal monetary policy for this economy is given by the Friedman rule, which sets the growth rate of money \( g \) equal to the discount factor \( \beta \). This eliminates the distortions associated with the presence of cash-in-advance constraints as they are non-binding in equilibrium.
heterogeneity, i.e., $\omega, \psi$, and $\nu$. The remaining parameters, viz $\beta, \theta, \delta, \gamma, \alpha, a$ and $g$ are taken directly from standard papers in the equilibrium business cycle literature, such as Hansen (1985) and Cooley and Hansen (1989). The range of values for the parameters $\omega, \psi$, and $\nu$ include the values chosen in the Prasad (1996)\(^7\). In particular, the fixed parameters are given by the following: $\beta = .99 ; \theta = .36 ; \delta = .025 ; a = 2.86 ; g = 1.024$

Since all of the fixed parameters are from models calibrated to U.S. data, the results here may be interpreted to be representative of countries that have experienced similar levels of development. To that end, our focus in the next section will be on the sub-sample of countries that fall into the “developed” or “industrialized” category.

To compute welfare costs of inflation, we calculate the increase in consumption that an individual would require to be as well off under the equilibrium allocation associated with the optimal monetary policy. Specifically, we solve for $x$ in the equation

$$
\bar{U} = \log (c^* (1 + x)) - \nu n_1^* - (1 - \psi) n_2^*,
$$

where $c^*, n_1^*, n_2^*$ are levels of consumption and work effort associated with monetary policy that sets $g = 1.024$, while $\bar{U}$ is the utility attained under the optimal policy which sets $g = \beta$. We calculate this loss, expressed as a percentage of output and also of consumption, for varying levels of each of the heterogeneity parameters. Figures 1, 2, and 3 below present our welfare cost computations as the parameters $\omega, \psi$, and $\nu$ are varied respectively, keeping all other parameters fixed.

First, we examine the effect of increasing $\omega$, which in our model represents the productivity differential between the skilled and unskilled sections of the labor force. In Figure 1, we see that welfare costs expressed as percentage of consumption and output decline as $\omega$ increases. The intuition underlying this feature is straightforward. Both types of work effort are decreasing in inflation, but an increase in the productivity differential reduces the loss of output associated with a given rate of inflation. Of course, in our model heterogeneity is of the ex-ante type; both types of workers belong to the same representative family and the “size of the cake” they share increases with $\omega$.

\(^7\) The cyclical features of our model are essentially similar to those of Cooley and Hansen (1989), and the Prasad (1996) model without adjustment costs. We do not present these results since our focus here is on the welfare costs of inflation. They are, however, available upon request.
Next, we present the welfare losses associated with changes in the parameter $\psi$. Recall that this preference parameter represents the weight assigned to the disutility of skilled effort, while $1 - \psi$ represents the corresponding weight assigned to the disutility of unskilled effort. In the economy described in the previous sections, there is a steady state relationship between the levels of employment of skilled and unskilled labor, (implied by equations (30) and (31)) which is given by

$$N_1 = \left[ \frac{\omega(1-\psi)}{\psi} \right]^{1/\nu} N_2. \quad (34)$$

Furthermore, in equilibrium, the respective real wages of skilled and unskilled labor are given by

$$w_{1r} = \frac{\psi}{1-\psi} w_{2r}. \quad (35)$$

The above relationship obviously follows from equations (13) and (14). It is clear that the parameter $\psi$ reflects the nature of composition of the workforce between skilled and unskilled workers and the wages they attract. It is also clear that the ratio of skilled to unskilled workers is monotonically decreasing in $\psi$, while the corresponding wage ratio is monotonically increasing in $\psi$. One can therefore interpret intermediate values of $\psi$ as reflecting a smaller degree of heterogeneity, while extreme values represent greater heterogeneity. Figure 2, then, presents us a result similar to the one presented in Figure 1: welfare costs tend to be lower in the extreme values of $\psi$ in the range $(0, 1)$.

In the last instance we take the elasticity of substitution $\frac{1}{\nu}$ between type one labor and type-two labor in the labor aggregation function (11) as a measure of heterogeneity. Figure 3 shows that welfare costs of inflation decrease as we increase the values of $\nu$. That is, decreasing the substitutability between the two types of labor lowers welfare losses due to inflation. Since lower substitutability between the two types of labor by definition implies greater heterogeneity, this result also points to the same conclusion.

To reiterate, the analysis carried out above points to an important implication of this model. Economies where agents are characterized by a higher degree of heterogeneity show lower costs of inflation, and as such they are likely to show higher
inflation rates. In other words, agents’ heterogeneity could contribute toward explaining the variations in the inflation experiences of different countries at any given point in time. The scope of the next section is to empirically estimate the correlation between inflation and agent’s heterogeneity.

5. Inflation and Agents’ Heterogeneity: An Empirical Analysis

In order to test whether agents’ heterogeneity indeed affects the policy maker’s decision over the optimal inflation level we compare the experiences of a number of countries over a period of time starting in 1960 and ending, in our most comprehensive case, in 2000. Our empirical strategy is to control for differences in institutional arrangements across countries so as to shed light on the correlation between human capital inequality and inflation. The data on inflation are drawn from The International Financial Statistics published by the International Monetary Fund. The sample comprises 108 countries, of which 33 are defined as developed economies (LDC = 0) and 44 are defined by Cukierman and Webb (1995) as democracies (dummy for authoritarian regime=0). However, the number of countries actually used in the estimation procedure is much smaller due to data availability constraints.

5.1 The Explanatory Variables.

The type of heterogeneity at work in the theoretical model is correlated with agents’ productivity as well as with the shadow value they assign to leisure. Also, it is affects the agents’ substitutability in the production process. A natural candidate for a measure of heterogeneity is human capital inequality. Differences in human capital attainment indeed produce heterogeneity that affects productivity, and the substitutability between agents in addition to the value assigned to non-working activities. Data for agents’ heterogeneity are provided by Castello and Domenech (2002) and refer to human capital inequality. Using the recent information contained in Barro and Lee’s (2001) data set about educational attainments, Castello and Domenech calculate a human capital Gini coefficient 

\[ G = 1 - 2 \int_0^1 A(y)dy \]

where \( A(y) \) is the Lorenz curve of the educational attainment distribution. The Lorenz curve plots the cumulative percentage of educational
attainment (human capital) reached by the bottom y-percent of the population. The Gini coefficient is a measure of human capital inequality that ranges from zero to one: in the case of perfectly equal distribution the Lorenz curve would coincide with the 45-degree lines and the Gini coefficient would be zero. Castello and Domenech (2002) propose two Gini coefficients, namely G25, the Gini coefficient computed using the population aged 25 and plus, and G15, the Gini coefficient computed using the population aged 15 and plus. While for the most part we will use the former, we will use the latter to check the robustness of our results. Both measures of human capital inequality are available for all 108 countries in the data set at times of 5-year interval starting from 1960.

It is now well established that the conduct of monetary policy and specifically the rate of growth of the money stock is the primary factor determining a country’s inflation rate. The actual policy pursued by the monetary authority depends on a number of factors some of which have an exquisitely political flavor. For instance there is now a large body of literature that relates central banks’ decisions to their independence from, or vulnerability to, political pressure, which may work to deviate the central bank’s attention from the pursuit of a price stability goal (e.g., Cukierman, Webb and Neyapti, 1992; Cukierman and Webb, 1995). The other variables we include in our data set reflect this type of argument. The measures of Central Bank independence (CBI), central bank vulnerability (vulnerability) and political instability (political change) come from the Cukierman and Webb (1995) data set. The CBI variable measures legal independence of central bank from political power. Cukierman et al., (1992) code central bank independence following two main principles. First of all, they code only a few narrow but relatively precise legal characteristics. Secondly, they only use the written information from central banks’ charters. The legal characteristics as described in the charters define a few important issues, namely:

(i) The appointment, dismissal and term of office of the central bank’s chief officer;
(ii) The policy formulation cluster and the resolution of possible conflicts over monetary policy between monetary and fiscal authorities;
(iii) The objectives of the central bank;
(iv) Limitations on the ability of the central bank to lend to the public sector and regulation of the modalities with which such lending can take place.
The way the single components of central bank’s legal independence are aggregated is fully described in Cukierman et al., (1992).

The Cukierman-Webb (1995) vulnerability variable takes its origin from raw data on the actual dates of changes of the governors of the central banks. To measure central bank vulnerability to political instability, Cukierman and Webb estimate the probability per month of a change in central bank governor conditional on being a time interval that follows a political transition. They show that although this probability decreases monotonically with the number of months that have elapsed since the last political transition, the estimated probability of a change in governor at the central bank is more than two times larger in periods within six months after a political transition than in periods that are more removed from political change. They then compute an index of the political vulnerability of the central bank (vulnerability), defined for each country in the Cukierman-Webb (1995) sample as the fraction of political transitions that are followed with a lag of 0 to 6 months by a replacement of the central bank governor. Cukierman and Webb (1995) illustrate that the highest level of central bank vulnerability occurs in the face of high level political transitions, which is then included among the explanatory variables.

The last variable we include is the degree of openness (openness) of an economy to the rest of the world. We measure this as the ratio of the sum of imports and exports over a country’s GDP. The argument is that the degree of exposure to international trade may increase the ability of a central bank to pre-commit to a given (low) inflation target.

The Cukierman-Webb variables described above are available for 67 countries from 1950 to 1989 although data for economies that achieved political independence or established a central bank after the 1950 start later. The Cukierman-Webb data set includes all the major industrial and developing economies, but excludes most Easter European countries. Table 1 reports the summary statistics for the main variables.

5.2 The Empirical Specification.
We estimate a model of the form

$$\pi_{it} = \alpha + x_{it} \beta + \eta_i + \epsilon_{it}$$

(36)

where $\pi_{it}$ is the inflation measure in country i in time t, $x_{it}$ is a set of explanatory variables specific to country i in time t and $\eta_i + \epsilon_{it}$ is the residual. We are interested in
estimating the $\beta$s. While the error component $\varepsilon_i$ has the usual properties (mean zero, uncorrelated with itself, uncorrelated with the vector $x$), the characteristics of the error component $\eta_i$ define the estimation strategy we will adopt. In particular, given the extreme heterogeneity of inflation experiences we observe in our sample, and the extreme differences of the institutional features of the countries considered, we opt for treating the country specific error component, $\eta_i$, as a fixed effect rather than a random variable. This amounts to estimating the following equation,

$$\pi_i - \bar{\pi}_i = \alpha + (x_i - \bar{x}_i)\beta + \varepsilon_i - \bar{\varepsilon}_i$$

where $\bar{\pi}_i = \sum_i \pi_i / T$, $\bar{x}_i = \sum_i x_i / T$, $\bar{\varepsilon}_i = \sum \varepsilon_i / T$. In the actual estimation the dependent variable has been transformed to reduce heteroskedasticity of the error and thus improve the efficiency of the estimate. Also, since a few countries had three-digit inflation rates in some years, using the untransformed inflation rate as a dependent variable would give undue weight to these outlying observations. Instead, we use $D = \frac{\pi}{1+\pi}$ as the dependent variable, as in Cukierman et al., (1992, 1995). The variable $D$ takes a value from zero to one.

5.3 The empirical results.

We begin by reproducing some of the results from the previous literature using our data set. In this way the actual impact of human capital inequality on inflation will be better evaluated. When the dependent variable $D$ is regressed on openness only, using a FE estimator or simply OLS on the pooled cross-section observations, the openness coefficient is negative and highly statistically significant, a results often highlighted in the empirical literature (Romer, 1993; Lane, 1995). The FE coefficient and standard error of openness is reported below

$$D = -0.0007(openness) + 0.15$$

(0.0001)  

(38)

The negative correlation between openness and inflation is robust to the inclusion of CBI among the explanatory variables, although it becomes statistically non-significant when variables representing the vulnerability of the central bank and high-level political change are included among the regressors.
The degree of independence of the central bank from political pressure CBI has often been found to have positive although a hardly statistically significant effect on inflation. Using our full sample we find a positive and statistically significant coefficient in the OLS and FE regressions. The CBI coefficients turn statistically non-significant and negative in the case of developed democracies for which the FE regression results are as follows

\[ D = -0.07(CBI) + 0.09 \]

\[ (0.06) \]  

(39)

For this very restricted group of countries the OLS estimate of CBI is negative and highly statistically significant, a result that reproduces the one found by Cukierman et al., (1992).

Our new empirical results are illustrated in tables 2-4. Table 2 reports the Fixed Effect estimation results obtained by using the full sample to estimate equation (37). The left hand side panel illustrates results where the dependent variable is D, while in the right hand side panel the dependent variable is the logarithmic transformation of the inflation rate \( \pi \). The Gini coefficient computed using the population of those aged 25 and over is consistently negative and statistically significant. The sign of these estimates suggests that countries where agents are differently endowed with human capital tend to have better inflation records, once we keep constant those institutional factors that may impact upon the commitment to price stability. However, this suggested link between human capital inequality and inflation does not consistently apply to all countries. For instance, Table 3 illustrates the Fixed Effect estimation results obtained by splitting the sample in Non-Authoritarian and Authoritarian regimes, left hand side panel and right hand side panel, respectively, of Table 3. When such a distinction is made we notice that the negative correlation between G25 and inflation does not hold for Authoritarian regimes where a mildly statistically significant positive correlation between these two variables emerges.

The results illustrated in Table 4 further illustrates that the relationship between human capital inequality and inflation may depend on other features of the economy that are broadly captured by the dummy variable for the state of development. For Less Developed Countries (LDC=1) we again find the negative correlation between the Gini
coefficient of the human capital distribution and inflation we initially found in the full sample estimates. However, in a sample of more developed countries (LDC=0) we find that human capital inequality increases inflation, a result that can be explained by our model where human capital inequality decreases the welfare costs of inflation thus opening a space where the commitment to price stability may be relaxed.

Note that these results are robust to (i) changes in the dependent variable (as illustrated in table 2 above), (ii) changes in the population used to compute the human capital inequality measure (G15 rather than G25). Also in most cases the use of OLS as an estimation technique does not radically change the results. For instance our OLS estimates for Central Bank vulnerability (vulnerability), which reproduce the results by Cukierman and Webb (1995), are not dramatically altered when the Gini measure of human capital inequality is included among the regressions. In such a regression the G25 variable has a negative, mildly statistically significant coefficient, which appears to be consistent with our FE estimates reproduced in table 2. (These results are available upon request).

6. Concluding Remarks

The objective of this paper was to examine the link between skill heterogeneity and the costs of inflation. This issue was addressed within a dynamic general equilibrium framework that incorporated ex-ante skill heterogeneity among workers. Numerical experiments based on a plausible parameterization of this model indicated that welfare costs of inflation relative to an optimal monetary policy decrease as skill heterogeneity increases. An implication of this feature is that a greater degree of skill heterogeneity would be associated with a greater tolerance for inflation, consequently implying a positive correlation between agent heterogeneity and inflation. We also conducted an empirical study based on a panel of several countries that lends some support to this hypothesis. If we focus on the experience of industrialized economies, the data supports a positive inflation-heterogeneity correlation. On the other hand, this is not true of less developed economies, in which the inflation heterogeneity correlation if found to be negative. However, the model economy we study in this paper, and its parameterization, is representative of developed economies, and to that end is only capable of explaining
the long run or cyclical features of such economies. We may therefore interpret the results as supportive of the theoretical implications of our model.
References


Figure 1: Welfare Costs as the Productivity of Skilled Workers Varies from 1.67 to 2.05. Other parameters are held at $\beta = 0.99; \theta = 0.36; \delta = 0.025; a = 2.86; g = 1.024; \nu = 0.4; \psi = 0.59$. (Welfare costs are measured relative to the optimal policy, which sets $g = \beta$)
Figure 2: Welfare Costs as the $\psi$ Varies from .4 to .8. Other parameters are held at $\beta = .99; \theta = .36; \delta = .025; a = 2.86; g = 1.024; \nu = .4; \omega = 1.67$. (Welfare costs are measured relative to the optimal policy, which sets $g = \beta$.)
Figure 3: Welfare Costs as $\nu$ from .4 to .8. Other parameters are held at $\beta = .99$; $\theta = .36$; $\delta = .025$; $a = 2.86$; $g = 1.024$; $\psi = .59$. (Welfare costs are measured relative to the optimal policy, which sets $g = \beta$.)
### Table 1 - Summary statistics for the main variables

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Obs.</th>
<th>Mean</th>
<th>Stand. Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflation $\pi$</td>
<td>100</td>
<td>36.3</td>
<td>114.0</td>
<td>2.68</td>
<td>920.5</td>
</tr>
<tr>
<td>$D = \frac{\pi}{1+\pi}$</td>
<td>100</td>
<td>0.11</td>
<td>0.09</td>
<td>0.03</td>
<td>0.52</td>
</tr>
<tr>
<td>G25</td>
<td>105</td>
<td>0.48</td>
<td>0.24</td>
<td>0.13</td>
<td>0.94</td>
</tr>
<tr>
<td>G15</td>
<td>108</td>
<td>0.45</td>
<td>0.23</td>
<td>0.11</td>
<td>0.91</td>
</tr>
<tr>
<td>Openness</td>
<td>98</td>
<td>66.2</td>
<td>42.9</td>
<td>10.9</td>
<td>243.0</td>
</tr>
<tr>
<td>CBI</td>
<td>57</td>
<td>0.34</td>
<td>0.12</td>
<td>0.12</td>
<td>0.69</td>
</tr>
<tr>
<td>Vulnerability</td>
<td>56</td>
<td>0.29</td>
<td>0.31</td>
<td>0</td>
<td>1.28</td>
</tr>
<tr>
<td>High-level pol. change</td>
<td>56</td>
<td>0.03</td>
<td>0.05</td>
<td>0</td>
<td>0.18</td>
</tr>
</tbody>
</table>

### Table 2. Inflation and human capital inequality, 1960-2000. The dependent variable is $D = \frac{\pi}{1+\pi}$ in the left hand panel and log $\pi$ in the right hand panel, where $\pi$ is the inflation rate. Fixed Effect Estimation results.

<table>
<thead>
<tr>
<th>Explan. variables</th>
<th>Inflation is D, FE 1960-2000</th>
<th>Inflation is log $\pi$, FE 1960-2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gini (pop. 25+)</td>
<td>-0.14** (-0.06)</td>
<td>-0.36** (0.15)</td>
</tr>
<tr>
<td></td>
<td>-0.44** (0.16)</td>
<td>-1.94** (0.66)</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.15)</td>
</tr>
<tr>
<td>Openness</td>
<td>----</td>
<td>0.001** (-0.0004)</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.04)</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Central Bank Ind.</td>
<td>----</td>
<td>0.31* (0.17)</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>2.76</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>(1.72)</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>(1.70)</td>
</tr>
<tr>
<td>Vulnerability (lag 0-6 months)</td>
<td>0.04 (0.17)</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.04)</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>----</td>
</tr>
<tr>
<td>High-level political change</td>
<td>0.04 (0.19)</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>-0.06</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>-0.04</td>
</tr>
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<td></td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>(0.19)</td>
<td>(0.19)</td>
</tr>
<tr>
<td></td>
<td>(0.19)</td>
<td>----</td>
</tr>
<tr>
<td>Constant</td>
<td>0.17*** (0.03)</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>0.14</td>
<td>1.41</td>
</tr>
<tr>
<td></td>
<td>2.87*** (0.09)</td>
<td>2.89**</td>
</tr>
<tr>
<td></td>
<td>(0.29)</td>
<td>(0.93)</td>
</tr>
<tr>
<td></td>
<td>(2.14)</td>
<td>(2.14)</td>
</tr>
<tr>
<td>No. of observations</td>
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<td>264</td>
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<tr>
<td></td>
<td>262</td>
<td>711</td>
</tr>
<tr>
<td></td>
<td>260</td>
<td>258</td>
</tr>
<tr>
<td>No. of groups</td>
<td>97</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>97</td>
</tr>
<tr>
<td>F test</td>
<td>5.10** (3.45**</td>
<td>3.62**</td>
</tr>
<tr>
<td></td>
<td>8.58**</td>
<td>3.91**</td>
</tr>
<tr>
<td></td>
<td>5.47**</td>
<td>----</td>
</tr>
</tbody>
</table>
Table 3. Inflation and human capital inequality. Democratic and non-democratic regimes, 1960-2000. The dependent variable is $D = \frac{\pi}{1 + \pi}$ where $\pi$ is the inflation rate. Fixed Effects Estimation results.

<table>
<thead>
<tr>
<th>Exp. Var.</th>
<th>FE Non-Authoritarian</th>
<th>FE Authoritarian (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gini (pop. 25+)</td>
<td>-0.27**</td>
<td>-0.48**</td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td>(0.16)</td>
</tr>
<tr>
<td>Openness</td>
<td>----</td>
<td>0.001**</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>(0.0004)</td>
</tr>
<tr>
<td>Central Bank Ind.</td>
<td>----</td>
<td>0.29*</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>(0.16)</td>
</tr>
<tr>
<td>Vulnerability</td>
<td>----</td>
<td>0.01</td>
</tr>
<tr>
<td>(0-6 months)</td>
<td>----</td>
<td>(0.04)</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>-0.04</td>
</tr>
<tr>
<td>High-level political change</td>
<td>----</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>----</td>
<td>(0.19)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.20***</td>
<td>0.18**</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.09)</td>
</tr>
<tr>
<td>No. of observations</td>
<td>386</td>
<td>239</td>
</tr>
<tr>
<td>No. of groups</td>
<td>44</td>
<td>43</td>
</tr>
<tr>
<td>F test</td>
<td>5.33**</td>
<td>4.15**</td>
</tr>
</tbody>
</table>

Notes:
(a) Because of the lack of variability of some variables within the sample of non-democratic countries, the last two columns illustrate Random Effect estimation results.
(b) The “High-level political change” variable has been replaced with “Low-level political change”.
**Table 4.** Inflation and human capital inequality. Developed and less developed countries, LDC = 0 and LDC = 1, respectively, 1960-2000. The dependent variable is $D = \frac{\pi}{1 + \pi}$ where $\pi$ is the inflation rate. Fixed Effects (FE) Estimation results.

<table>
<thead>
<tr>
<th>Exp. Var.</th>
<th>FE, LDC = 1</th>
<th>FE, LDC = 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gini (pop. 25+)</td>
<td>-0.17**</td>
<td>0.53**</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.19)</td>
</tr>
<tr>
<td>Openness</td>
<td>0.0008</td>
<td>0.002**</td>
</tr>
<tr>
<td></td>
<td>(0.0006)</td>
<td>(0.0006)</td>
</tr>
<tr>
<td>Central Bank Ind.</td>
<td>1.04**</td>
<td>-0.14</td>
</tr>
<tr>
<td></td>
<td>(0.39)</td>
<td>(0.20)</td>
</tr>
<tr>
<td>Vulnerability (0-6 months)</td>
<td>0.004</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>High-level political change</td>
<td>-0.04</td>
<td>0.89*</td>
</tr>
<tr>
<td></td>
<td>(0.25)</td>
<td>(0.50)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.21***</td>
<td>0.0002</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.09)</td>
</tr>
<tr>
<td>No. of observations</td>
<td>534</td>
<td>120</td>
</tr>
<tr>
<td>No. of groups</td>
<td>73</td>
<td>20</td>
</tr>
<tr>
<td>F test</td>
<td>4.62**</td>
<td>3.08**</td>
</tr>
</tbody>
</table>

Note: ** denotes significance at the 1% level, * at the 10% level.
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