Inflation and income inequality in a Schumpeterian economy with menu costs

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Abstract

This study incorporates heterogeneous households into a monetary Schumpeterian growth model via menu costs to explore the effect of inflation on income inequality. The source of income inequality stems from the unequal distribution across households' assets. Given that households face the same wage rate, inflation that leads to a monotonically decreasing effect on economic growth helps mitigate income inequality by weakening the contribution of asset income relative to wage income.

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1 Introduction

As the degree of income inequality has risen in many developed countries over the past few decades (Saez and Zucman (2016)), the issue of income inequality is widely discussed in policy circles and academics. This fact affects the assessment of monetary policy, which is conventionally considered as targeting at price stability and economic growth. Now its impact on income inequality – how it benefits or harms different income groups in society – has been receiving more attention.[1]

This study contributes to the literature by exploring the effect of inflation on both economic growth and income inequality in a Schumpeterian framework. Based on the model formulated by Oikawa and Ueda (2018), who incorporate menu costs for analyzing the relationship among inflation, innovation and growth, we extend it by considering elastic labor supply and heterogeneous households featuring different asset holdings as in Chu (2010). In this model, income inequality comes from the unequal asset distribution and is increasing in the ratio of asset income to wage income. In the case of inelastic labor supply, as wage income is equally distributed across households, inflation affects income inequality by altering households' income portfolios. Specifically, inflation that causes a monotonically decreasing effect on real economic growth mitigates income inequality by lowering the return rate of assets and then the ratio of asset income to wage income. Furthermore, in the general case of elastic labor supply, inflation generates more negative impacts on income inequality because the households' value on leisure decreases wage income, causing a rise in the ratio of asset income relative to wage income.[2]

In addition to the existing studies in inflation and innovation (for example, Chu and Cozzi (2014) and Huang *et al.* (2017)), and those in inflation and inequality (for example, Coibion *et al.* (2017) and Menna and Tirelli (2017)), this study is most closely related to Chu *et al.* (2019), who explore a similar issue in inflation and income inequality. Specifically, by introducing money demand via CIA constraints into a Schumpeterian growth model with random quality improvement, Chu *et al.* (2019) find that inflation that leads to an inverted-U effect on economic growth generates the same effect on income inequality. This study complements their interesting study by considering the analysis of inflation and income inequality in a framework with menu costs, which serves as an important workhorse model in the current analysis for monetary policy (Woodford (2011)). Moreover, in the cashless economy described in this model, inflation affects income inequality only through changing the rate of economic growth and the return rate of assets (i.e., the real interest rate), yet leaving the asset value (relative to wage) unchanged. This mechanism behind the inflation-inequality relation differs from the counterpart in Chu *et al.* (2019).[3]

[1] See, for example, Coibion *et al.* (2017) and many among others for detailed discussions.

[2] This theoretical prediction on a negative relationship between inflation and income inequality is supported by recent empirical studies, such as Monnin (2014) who finds a strong negative link between inflation and income inequality based on a panel of 10 OECD countries, and Coibion *et al.* (2017) who show that contractionary monetary policy increases inequality in households' income in the US. Nevertheless, there is not yet a consensus regarding the link between inflation and income inequality. For example, Romer and Romer (1998) and Albanesi (2007) tend to indicate a positive relationship, whereas Chu *et al.* (2019) find an inverted-U relationship.

[3] Under the assumption of CIA constraints on R&D, Chu *et al.* (2019) show that inflation affects income inequality through both the return rate of assets and the asset value relative to wage.

2 Model

Consider a cashless economy, in which the monetary authority directly controls the inflation rate. Throughout the analysis, we focus on the balanced growth path. Denote by g the growth rate of a real variable, and by π the growth rate of an aggregate price index embedding quality improvement. Thus, the growth rate of a nominal variable is denoted by $n \equiv g + \pi$, and we restrict our analysis to the case with $n \geq 0$.

2.1 Households

There is a unit continuum of infinitely-lived households indexed by $h \in [0, 1]$, who are identical in preferences over consumption $c_{t'}(h)$ and leisure $l_{t'}(h)$ but possess different levels of asset holdings. Each household's lifetime utility is given by

$$U_t = \int_t^{\infty} e^{-\rho(t'-t)}[\ln c_{t'}(h) + \varphi \ln(1 - l_{t'}(h))]dt', \tag{1}$$

where $\rho > 0$ represents the subjective discount rate and $\varphi > 0$ determines the leisure preference. Household h's asset-accumulation equation is

$$\dot{a}_t(h) = r_t a_t(h) + w_t l_t(h) - c_t(h), \tag{2}$$

where $a_t(h)$ is the real asset value, r_t is the real interest rate, and w_t is the real wage rate. Solving the standard utility-maximization problem yields the optimal decision of consumption and leisure:

$$w_t[1 - l_t(h)] = \varphi c_t(h) \tag{3}$$

and the intertemporal optimal condition for household h:

$$\dot{c}_t(h)/c_t(h) = r_t - \rho. \tag{4}$$

Equation (4) shows that all households share an identical growth rate of real consumption such that $\dot{c}_t/c_t = \dot{c}_t(h)/c_t(h) = r - \rho$, where $c_t \equiv \int_0^1 c_t(h)dh$ denotes the total consumption by all households.

2.2 Final goods

Final goods are produced competitively by using a unit continuum of intermediate goods according to the standard Cobb-Douglas aggregator given by

$$y_t = \exp\left\{\int_0^1 \ln\left[\sum_j \lambda^j x_t(\varepsilon, j)\right] d\varepsilon\right\}, \tag{5}$$

where $x_t(\varepsilon, j)$ is the quantity of j quality intermediate goods in industry $\varepsilon \in [0, 1]$ at time t, and $\lambda > 1$ captures the size of quality increment generated by each innovation. Solving the profit-maximization problem yields the demand function of $x_t(\varepsilon, j)$:

$$x_t(\varepsilon, j) = P_t y_t / p_t(\varepsilon, j) = E_t / p_t(\varepsilon, j), \tag{6}$$

where E_t is the aggregate nominal output and P_t is the quality-adjusted aggregate price index, defined by $\ln P_t = \int_0^1 \ln [p_t(\varepsilon)/\lambda_t(\varepsilon)]\, d\varepsilon$. For convenience, we denote the initial values in period $t = 0$ without time subscripts. Assuming $E = 1$, we have $y_t = E_t/P_t = e^{nt}/(Pe^{\pi t}) = e^{gt}/P$ and $y = 1/P$.

2.3 Intermediate goods

Intermediate goods in industry ε are manufactured by using one unit of labor $l_{x,t}(\varepsilon)$ regardless of quality. Standard Bertrand price competition implies that the quality leader in each industry adopts the limit-pricing strategy to exclude the entry of its potential rivals. Therefore, the real period profit of the monopolist is

$$\Pi_t(p_t(\varepsilon, j)) = \frac{p_t(\varepsilon, j) - W_t}{p_t(\varepsilon, j)} \frac{E_t}{P_t} = \underbrace{\frac{\xi_t(\varepsilon, j) - W}{\xi_t(\varepsilon, j)}}_{\Pi^0(\xi_t(\varepsilon, j))} y_t, \tag{7}$$

where $W_t = P_t w_t$ is the nominal wage rate and $\xi_t(\varepsilon, j) = p_t(\varepsilon, j)e^{-nt}$ is the relative price to E_t. Moreover, the profit-maximizing price is $\xi^* = \lambda W$.

2.3.1 Pricing under menu costs

We assume that when firms change their prices in period t, they need to incur $\kappa > 0$ units of final goods as menu costs, which makes the price of each intermediate good sticky. The expression $\xi_t(\varepsilon, j) = p_t(\varepsilon, j)e^{-nt}$ indicates that the relative price decreases at the rate of $n = g + \pi$ for the rises in the real wage rate and aggregate price. Suppose that in period t_{i+1} for $i = 0, 1, 2, \cdots$, firms pay menu costs and reset the relative price at ξ_{i+1}. Then the real present value of a monopolist at entry is given by

$$V_t = \sum_{i=0}^{\infty} \left\{ \int_{t_i}^{t_{i+1}} \Pi_{t'}(\xi_i e^{-n(t'-t_i)}) e^{-(r+\eta)(t'-t)} dt' - \kappa y_{t_{i+1}} e^{-(r+\eta)(t_{i+1}-t)} \right\}, \tag{8}$$

where $\xi_t = \xi_i e^{-n(t-t_i)}$, and t_i is the timing of price changes with $t_0 = t$. η is the entry rate of new firms, also indicating the exit rate of existing firms due to creative destruction.

As shown in Sheshinski and Weiss (1977) and Oikawa and Ueda (2018), the optimal pricing strategy for firms is to obey the following Ss rule, with the maximum and minimum price, S and s, respectively, given by

$$S = \xi^* = \lambda W; \qquad \text{and} \qquad s = Se^{-n\Delta}, \tag{9}$$

where Δ denotes the time interval between s and S. Monopolists that enter the market in period

t set the relative price at S initially, and their firm value is now described by

$$\begin{aligned} V_t &= \sum_{i=0}^{\infty} \left\{ \int_{t+i\Delta}^{t+(i+1)\Delta} \Pi_{t'}(Se^{-n(t'-t-i\Delta)}) e^{-(r+\eta)(t'-t)} dt' - \kappa y e^{g(t+(i+1)\Delta)} e^{-(r+\eta)(t+(i+1)\Delta-t)} \right\} \\ &= \sum_{i=0}^{\infty} \left\{ \int_{0}^{\Delta} \Pi^0(Se^{-nt''}) y e^{g(t''+i\Delta+t)} e^{-(r+\eta)(t''+i\Delta)} dt'' - \kappa y e^{g(t+(i+1)\Delta)} e^{-(r+\eta)(i+1)\Delta} \right\} \\ &= \frac{ye^{gt}}{1-e^{-(\rho+\eta)\Delta}} \left\{ \int_0^{\Delta} \Pi^0(Se^{-nt''}) e^{-(\rho+\eta)t''} dt'' - \kappa e^{-(\rho+\eta)\Delta} \right\} \\ &= y_t \left\{ \frac{1}{\rho+\eta} - \frac{1/\lambda}{1-e^{-(\rho+\eta)\Delta}} \frac{1-e^{-(\rho+\eta-n)\Delta}}{\rho+\eta-n} - \frac{\kappa e^{-(\rho+\eta)\Delta}}{1-e^{-(\rho+\eta)\Delta}} \right\}, \end{aligned} \tag{10}$$

where (7) is used. Define $v_t \equiv V_t/y_t$ as the normalized firm value. Thus, the optimal time interval $\Delta = \Delta(\eta, n)$ maximizing v is determined by

$$\begin{aligned} \frac{dv}{d\Delta} = 0 &\Leftrightarrow v(\rho+\eta) - \kappa(\rho+\eta) = \Pi^0(Se^{-n\Delta}) \\ &\Leftrightarrow \lambda\kappa = \frac{e^{n\Delta}[1-e^{-(\rho+\eta)\Delta}]}{\rho+\eta} - \frac{1-e^{-(\rho+\eta-n)\Delta}}{\rho+\eta-n}, \end{aligned} \tag{11}$$

where $\Pi^0(Se^{-n\Delta})$ from (7) is applied again. Substituting (11) back into (10) yields the optimal $v = v(\eta, n)$ such that

$$v = \frac{1}{\rho+\eta}\left(1 - \frac{e^{n\Delta}}{\lambda}\right) + \kappa. \tag{12}$$

2.3.2 Firm distribution

Due to menu costs and firm entry, the $Ss-$pricing generates heterogeneity in prices among industry leaders. Oikawa and Ueda (2018) show that the stationary distribution of real prices ξ among firms is given by

$$f(\xi(t')) = \frac{\eta}{1-e^{-\eta\Delta}} e^{-\eta t'}, \quad \forall \eta > 0. \tag{13}$$

2.4 R&D and entry

A product with a better quality comes from R&D. We assume that β units of R&D workers are required to generate a new innovation, which implies an entry rate of $\eta = l_{r,t}/\beta$, where $l_{r,t}$ represents the measure of aggregate labor devoted to the R&D sector. Free entry into the R&D sector leads to zero expected profits for entrants such that $P_t V_t = \beta W_t$ for a positive η, which implies $\beta W = v$.

3 Stationary Equilibrium

Denote the aggregate level of labor supply, manufacturing labor, asset holdings and intermediate goods by $l_t = \int_0^1 l_t(h)dh$, $l_{x,t} = \int_0^1 l_{x,t}(\varepsilon)d\varepsilon$, $a_t = \int_0^1 a_t(h)dh$ and $x_t = \int_0^1 x_t(\varepsilon)d\varepsilon$, respectively.

The general equilibrium is defined as follow.

Definition 1. *The general equilibrium consists of the sequences of aggregate variables* $\{a_t, c_t, y_t, E_t, x_t, l_t, l_{x,t}, l_{r,t}\}_{t=0}^{\infty}$*, individual firms' decisions* $\{l_{x,t}(\varepsilon), \xi_t(\varepsilon), \Delta\}_{t=0}^{\infty}$*, household h's choices* $\{a_t(h), c_t(h), l_t(h)\}_{t=0}^{\infty}$*, and aggregate prices* $\{P_t, p_t(\varepsilon), W_t, r_t, V_t\}_{t=0}^{\infty}$*, for* $h \in [0,1]$ *and* $\varepsilon \in [0,1]$.

At each instant of time, households and firms solve their optimization problems, and all markets clear. Specifically, the asset market clears such that $V_t = a_t$. The labor market clears such that

$$l_{x,t} + l_{r,t} = l_t. \tag{14}$$

Additionally, the final goods market clears such that

$$c_t + \kappa f(\xi(\Delta)) y_t = y_t, \tag{15}$$

where the demand of final goods (for consumption and paying menu costs) equals the aggregate production of final goods.

3.1 Equilibrium allocations

The aggregate manufacturing labor is

$$l_x = \int_0^1 \frac{E_t}{p_t(\varepsilon)} d\varepsilon = \int_0^1 \frac{1}{\xi_t(\varepsilon)} d\varepsilon = \int_0^{\Delta} f(\xi(t')) \frac{1}{\xi(t')} dt' = \frac{\eta}{(\eta - n)\xi_0} \frac{1 - e^{-(\eta - n)\Delta}}{1 - e^{-\eta\Delta}}, \tag{16}$$

where $\xi_0 = \xi^*$. The aggregate labor supply is obtained by aggregating (3) by h and using (15) such that

$$l = 1 - \varphi \frac{P_t c_t}{W_t} = 1 - \frac{\varphi}{W} [1 - \kappa f(\xi(\Delta))] = 1 - \frac{\lambda\varphi}{\xi_0} \left[1 - \frac{\kappa\eta e^{-\eta\Delta}}{1 - e^{-\eta\Delta}}\right]. \tag{17}$$

Both (16) and (17) are functions of two endogenous variables η and n that determine the stationary equilibrium. Substituting $l_r = \beta\eta$, (16), and (17) into (14) yields the first equation used for solving η and n:

$$\frac{\lambda\varphi}{\xi_0} \left[1 - \frac{\kappa\eta e^{-\eta\Delta}}{1 - e^{-\eta\Delta}}\right] + \beta\eta + \frac{\eta}{(\eta - n)\xi_0} \frac{1 - e^{-(\eta - n)\Delta}}{1 - e^{-\eta\Delta}} = 1. \tag{18}$$

The real economic growth rate is $g = \eta \log \lambda$, which, together with $n(\pi) \equiv g(\pi) + \pi$, is the second equality for solving η and n. Consequently, the stationary equilibrium is pinned down for a given rate of inflation. Moreover, as discussed in Lemma 2 and 3 in Oikawa and Ueda (2018), inflation reduces the value of entering firms and discourages innovation, causing a negative effect on the real economic growth rate. Therefore, the inflation rate that maximizes the real economic growth rate is given by $\bar{\pi} = -\bar{g}$, implying a zero nominal growth rate $\bar{n} = 0$.

4 Inflation and income inequality

In this section, we follow García-Peñalosa and Turnovsky (2006) and Chu *et al.* (2019) to show that the wealth distribution on the balanced growth path is stationary in this monetary

Schumpeterian economy with menu costs. We then examine the effect of inflation on income inequality.

4.1 Wealth Distribution

Define $\theta_a(h) \equiv a(h)/a$ as the share of wealth owned by household h at the initial balanced growth path, which has a general distribution function with a mean of one and a standard deviation of $\sigma_a > 0$. Aggregating (2) by h yields

$$\dot{a}_t = r_t a_t + w_t l_t - c_t. \tag{19}$$

Combining (2) with (19) and using (3) yield the dynamics of $\theta_{a,t}(h)$:

$$\frac{\dot{\theta}_{a,t}(h)}{\theta_{a,t}(h)} = \frac{\dot{a}_t(h)}{a_t(h)} - \frac{\dot{a}_t}{a_t} = \frac{c_t - w_t l_t}{a_t} - \frac{c_t(h) - w_t l_t(h)}{a_t(h)} = \frac{(1+\varphi)c_t - w_t}{a_t} - \frac{(1+\varphi)c_t(h) - w_t}{a_t(h)},$$

which can be rewritten as

$$\dot{\theta}_{a,t}(h) = \frac{(1+\varphi)c_t - w_t}{a_t}\theta_{a,t}(h) - \frac{(1+\varphi)c_t\theta_{c,t}(h) - w_t}{a_t}, \tag{20}$$

where $\theta_{c,t}(h) \equiv c_t(h)/c_t$ is the share of consumption by household h at time t. Using $\dot{c}_t/c_t = \dot{c}_t(h)/c_t(h)$ from (4), we show that $\theta_{c,t}(h)$ is time invariant and equals to $\theta_c(h)$ for all t because $\dot{\theta}_{c,t}(h)/\theta_{c,t}(h) = \dot{c}_t(h)/c_t(h) - \dot{c}_t/c_t = 0$. Holding constant the inflation rate, the real economic variables $\{c_t, w_t, a_t\}$ all grow at the rate of g on the balanced growth path. (2) as a result implies $(1+\varphi)c_t - w_t = \rho a_t$ and the coefficient associated with $\theta_{a,t}(h)$ in (20) is reduced to $\rho > 0$. Therefore, the one-dimensional differential equation described in (20) indicates that $\dot{\theta}_{a,t}(h)$ must be zero along the balanced growth path, given that $\theta_{a,t}(h)$ is a state variable.[4] Moreover, applying $\dot{\theta}_{a,t}(h) = 0$ into (20) yields

$$\theta_c(h) - 1 = \frac{\rho a_t}{(1+\varphi)c_t}\left[\theta_a(h) - 1\right]. \tag{21}$$

4.2 Income distribution

The real income earned by household h and the aggregate real income earned by all households are $I_t(h) = r_t a_t(h) + w_t l_t(h)$ and $I_t = r_t a_t + w_t l_t$, respectively. Combining both equations yields the share of income by household h:

$$\theta_{I,t}(h) \equiv \frac{I_t(h)}{I_t} = \frac{r_t a_t(h) + w_t l_t(h)}{r_t a_t + w_t l_t} = \frac{r_t a_t \theta_a(h) + w_t - \varphi c_t \theta_c(h)}{r_t a_t + w_t - \varphi c_t}, \tag{22}$$

[4] It is useful to note that the model features transitional dynamics because of the heterogeneity of firms' pricing. Therefore, upon a change of the inflation rate, the aggregate economy experiences transitional dynamics before reaching the new balanced growth path, and the wealth distribution on the new balanced growth path may be different from the one on the old balanced growth path. We assume that inflation has a negligible effect on wealth inequality and thus take the degree of wealth inequality as given when analyzing its effect on income inequality, which is significant as shown in previous studies.

where (3), $\theta_{a,t}(h) = \theta_a(h)$ and $\theta_{c,t}(h) = \theta_c(h)$ are used. When analyzing the effect of inflation on income inequality, I first consider the special case of inelastic labor supply, captured by $\varphi = 0$. In this case, the distribution function of income share $\theta_{I,t}(h)$ has a mean of one and the following standard deviation:

$$\sigma_{I,t} = \sigma_I \equiv \sqrt{\int_0^1 [\theta_{I,t}(h) - 1]^2 dh} = \frac{r_t a_t / w_t}{1 + r_t a_t / w_t} \sigma_a = \frac{\beta(\rho + g)}{1 + \beta(\rho + g)} \sigma_a. \tag{23}$$

where $a_t / w_t = V_t / w_t = v y_t / (W E_t / P_t) = v / W = \beta$ is obtained by using the zero profit condition for R&D (i.e., $\beta W = v$) and the asset market clearing condition (i.e., $a_t = V_t$). Similar to the findings in Chu *et al.* (2019), σ_I rises when the asset income $r_t a_t$ increases relative to wage income w_t, because an unequal distribution of wealth is the source of income inequality. Then, the aggregate effect of inflation on income inequality can be decomposed into two channels, through affecting the *asset value* (i.e., a_t / w_t) and the *interest rate* (i.e., r_t), respectively. Nevertheless, in this cashless economy where households and firms are not subject to any cash constraints, inflation plays no role in altering the asset value, which is different from the situation in Chu *et al.* (2019). Therefore, inflation only operates through the interest-rate channel to reduce income inequality by retarding economic growth, which is maximized at $n = 0$ ($\bar{g} = -\bar{\pi}$).

In the general case of elastic labor supply, the income share of household h in (22) becomes

$$\theta_{I,t}(h) = \frac{[\rho + g - \rho\varphi/(1+\varphi)] a_t}{(\rho + g) a_t + w_t - \varphi c_t} [\theta_a(h) - 1] - 1, \tag{24}$$

where (3) and (21) are used. The standard deviation of income distribution is now given by

$$\sigma_I = \frac{(\rho + g + \varphi g) a_t}{(\rho + g + \varphi g) a_t + w_t} \sigma_a = \frac{\beta(\rho + g + \varphi g)}{1 + \beta(\rho + g + \varphi g)} \sigma_a, \tag{25}$$

where $c_t = (\rho a_t + w_t)/(1 + \varphi)$ from (19) and $a_t / w_t = \beta$ are applied. As compared to the case of inelastic labor supply, the presence of elastic labor supply weakens the role of wage income relative to asset income in each household's income portfolio, because people tend to value leisure and supply less labor. The asset income (whose heterogeneity is the source of income inequality) as a result contributes more to households' total income. A change in the economic growth rate therefore yields a stronger impact on income inequality in this case, which is captured by the term φg in (25). This feature is similar to the counterpart in Chu (2010), who focuses on the policy implications of patent protection and R&D subsidies instead. In this general case, the degree of income inequality is still decreasing in the inflation rate. Proposition 1 summarizes the above results.

Proposition 1. *The degree of income inequality is decreasing in the inflation rate. Inflation has a more negative effect on income inequality in the case of elastic labor supply than the case of inelastic labor supply.*

5 Conclusion

In this study, we explore the effect of inflation on income inequality in a monetary Schumpeterian framework developed by Oikawa and Ueda (2018). We find that differing from Chu *et al.* (2019) who incorporate money demand through CIA constraints on consumption and R&D, in the present study, inflation only affects income inequality through the interest-rate effect in a cashless economy, without operating through the asset-value effect. Therefore, inflation that stifles economic growth mitigates income inequality. In this sense, when conducting monetary policy, the central bank faces a tradeoff between economic growth and income inequality.

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