Aggregate Evidence of Nominal Rigidities and the Inflation-Output Trade-Off: The Relationship between the Income Share of Labor and the Rate of Inflation

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Abstract

In order for an inflation-output trade-off to arise due to nominal rigidities that make inflation distort price-setting, e.g. through sticky prices or monetary misperceptions, the income share of labor must move together with the rate of inflation. We find that it does, in the U.S. and other OECD countries, with correlation coefficients as high as .9. It is difficult to explain this co-movement without nominal rigidities, since the income share of labor is not likely to impact monetary policy, and is independent of most variables and shocks, including productivity shocks. Furthermore, these correlations remain significant when controlling for other factors that can affect the income share of labor, mainly the degree of competition. The observed co-movement is evidence of monetary non-neutrality and the relevance of nominal rigidities, but not necessarily of an inflation-output trade-off.

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1 Introduction

The hypothesis that money affects aggregate real economic variables in the short run, in spite of being neutral in the long run, is one of the most controversial issues in economics, mainly due to a lack of convincing empirical evidence of short-run non-neutrality and its relevance at the aggregate level. Despite this, much effort has been exerted studying so-called nominal rigidities through which money can affect the real economy, and using these frameworks not only to study monetary policy, but also to guide it. This effort was sparked by the infamous Phillips (1958) curve, which did not stand the test of time, but has nevertheless had an enormous impact on the field. In fact, a key feature in later contributions has been to rationalize why the Phillips curve shifts over time, thus justifying the deterioration of the original empirical evidence. As a consequence, many appear to have accepted that nominal rigidities are not easily detectable in aggregate data, and some have turned to look for these in disaggregate data, see for example Bils and Klenow (2004).[1] However, by construction, such studies cannot demonstrate the impact of nominal rigidities at the aggregate level, just whether or not they are relevant at the individual level. The present paper studies the effect money can have on real aggregate variables by distorting price-setting through nominal rigidities, in order to assess the relevance of these empirically. We find evidence of nominal rigidities distorting price-setting in U.S. aggregate data in that the income share of labor is highly correlated (.71) with the rate of inflation. For other countries we find even higher correlations (.86). While this finding is consistent with an inflation-output trade-off, such a trade-off is not necessarily implied.

The main difficulty with identifying the impact of nominal rigidities in aggregates is that economic theory predicts that most aggregate variables should be related even without such rigidities. For example, Freeman and Huffman (1991) argue that a positive co-movement between inflation and output can be explained without nominal rigidities by both variables reacting to productivity shocks, since such shocks would tend to affect interest rates, and therefore the money supply endogenously through bank deposits. The problem is attenuated by the fact that monetary policy is a function of aggregates, including output. For example, Wang and Wen (2005) argue that many of the features we observe in U.S. inflation and output data that can look like evidence of nominal rigidities is consistent with what we would observe in a model without nominal rigidities when policy follows the Taylor (1993) rule. This is why the present study focuses on the income share of labor instead of output. It is an aggregate variable that economic theory

[1] The evidence for hyperinflations having a negative impact on real aggregate output is very convincing. However, these situations are considered abnormalities, in the sense that the channels through which extremely high inflation affects real variables are considered different from those through which moderate inflation can have an impact.

predicts should be independent of shocks to productivity, government spending, household preferences, and most other shocks usually considered relevant for business cycles, but that is affected by nominal rigidities through the way these distort price-setting. Also, the income share of labor is not usually considered to have an impact on monetary policy, nor does it depend on variables usually thought to influence policymaking.[2]

Many a hypothesis has been put forward describing nominal rigidities that could make money affect the real aggregate economy by distorting price-setting. The most prominent ones are menu costs (Calvo (1983) and Rotemberg (1982)), negotiation costs (Taylor (1993)), monetary misperceptions (Lucas (1972)) and costly information-gathering (Mankiw and Reis (2002)). Our framework encompasses all of these in a general model of the aggregate impact of price-setting distortions. There are two distinct effects, one working through relative prices, the other through the average mark-up. By making price-adjustment idiosyncratic, nominal rigidities distort relative prices, reducing total factor productivity as a result of the cost-minimizing mix of intermediate goods differing from the efficient mix, hence reducing output and welfare. At the same time, nominal rigidities affect the level of the mark-ups households end up paying, which can reduce or raise output and welfare, depending on whether they raise or lower the average mark-up and dead-weight loss from imperfect competition. The existence of an inflation-output trade-off requires that the average mark-up fall with inflation, and that this effect be greater than that through relative prices and total factor productivity. Since the relative strength of the two effects will depend on the degree of competition and the dispersion in productivity across producers, both of which are likely to vary over time, the inflation-output relationship is likely to be unstable, and could even change sign. In contrast, both of the above-mentioned effects contribute to raise the income share of labor, so nominal rigidities should be easier to observe there than in output. Hence, assuming that inflation distorts price-setting due to nominal rigidities, the income share of labor should be positively related to the rate of inflation, as we find for the U.S. and other countries.

Without nominal rigidities that distort price-setting, changes in the income share of labor must, according to our theoretical framework, be due to variations in the degree of competition. As mark-ups are reduced due to intensified competition, the share of income that goes to profits falls, and the fraction that goes to labor and capital increases. While inflation has no impact on the degree of competition in the absence of nominal rigidities, the causality could go in the opposite direction, since output increases with

[2] In a real business cycle model in the tradition of Kydland and Prescott (1982) with perfect competition, the income share of labor equals the exogenous constant $1 - \alpha$, which is the elasticity of output with respect to the labor input.

the degree of competition, which could trigger inflation when monetary policy responds to output. However, if this were the cause of the observed co-movement between the income share of labor and the rate of inflation, this co-movement should be weaker than that between inflation and output, which is contrary to what we observe in the data. The reason is that productivity shocks, considered the most important source of business cycles, would affect output, and hence inflation, but have no impact on the income share of labor. This applies to any shock or variable that might conceivably affect the income share of labor and that generates inflation by monetary policy reacting to output, interest rates or any other variable affected by productivity shocks. Since most economic variables are sensitive to productivity shocks, and we do not observe any stronger co-movements with inflation than that of the labor share, and because it is unlikely that the labor share affect money directly, we find that nominal rigidities distorting price-setting is the most plausible explanation of the observed co-movement between the income share of labor and inflation. This is confirmed by the co-movement remaining significant when controlling for changes in the degree of competition, both for the U.S. and other countries.

Our dynamic general equilibrium model builds on that of Blanchard and Kiyotaki (1987). It consists of an infinite number of a priori identical monopolistically competing producers that rent capital and labor from households in competitive factor markets to produce differentiated intermediate goods that households purchase to compose final goods. The next three sections present the producers, households and equilibrium conditions, respectively. The following three sections study how nominal rigidities impact total factor productivity, factor markets and aggregate output, and the income share of labor, respectively, by distorting price-setting. Finding that evidence of nominal rigidities should be easiest to observe in the income share of labor, the subsequent section shows that this variable is highly correlated with inflation in U.S. data, and considers alternative explanations for this. We then study the correlation between these two variables in other OECD countries.

2 Producers

In any period t, each of the continuum of measure one of identical households produces y_t units of final good by combining a continuum of differentiated intermediate goods x_{it} indexed by $i \in [0,1]$, so that

$$y_t = \left(\int_0^1 (\gamma_{it} x_{it})^{\frac{\theta_t - 1}{\theta_t}} \, di \right)^{\frac{\theta_t}{\theta_t - 1}} \tag{1}$$

where $\theta_t \in (1, \infty)$ is the elasticity of substitution between any two intermediate goods. This is the Dixit-Stiglitz aggregator modified to incorporate productivity shocks $\gamma_{it} > 0$ that can change the relative weight of each intermediate good in the production of the final good, as well as the general productivity of intermediate goods in the production of the final good, see Dixit and Stiglitz (1977).[3] Assuming intermediate goods are the only inputs required to produce final goods, each household chooses the optimal mix of these so as to minimize the cost of providing final goods by solving

$$\min_{\{x_{it}\}_{i=0}^{1}} \int_0^1 P_{it} x_{it} di \tag{2}$$

subject to the production function (1), where P_{it} is the period-t price of intermediate good i. The resulting demand for intermediate good i from each of the households is

$$x_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\theta_t} \gamma_{it}^{\theta_t - 1} y_t \tag{3}$$

for all $i \in [0, 1]$. Inserting for this demand (3) into the production function for final goods (1) yields

$$P_t = \left(\int_0^1 \left(\frac{P_{it}}{\gamma_{it}} \right)^{1-\theta_t} di \right)^{\frac{1}{1-\theta_t}} \tag{4}$$

which is the marginal cost of producing the final good. It also represents the price of the final good, since all the identical households can compose identical final goods at identical cost. Aggregating intermediate-good demands (3) across all households, we find the aggregate demand for intermediate good i to be

$$X_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\theta_t} \gamma_{it}^{\theta_t - 1} Y_t \tag{5}$$

where Y_t is the aggregate demand for final goods at time t.

In every period t, intermediate-good producer i finds the optimal mix of inputs, capital k_{it}, labor n_{it} and land l_{it}, so as to minimize its production costs by solving

$$\min_{k_{it}, n_{it}, l_{it}} R_t k_{it} + W_t n_{it} + F_t l_{it} \tag{6}$$

[3]The γ_{it} could also be interpreted as taste shocks, but the composition of the final good would then change over time, making it difficult to compare final goods produced at different times.

subject to its production technology

$$X_{it} = z_{it} k_{it}^{\alpha} n_{it}^{1-\alpha-\nu} l_{it}^{\nu} \tag{7}$$

where W_t is the nominal wage, R_t is the nominal rental rate of capital, while F_t is the nominal rental rate of land. The weight each of these factors carry in production is determined by the coefficients $\alpha \in (0, 1)$ and $\nu \in (0, 1)$. As usual, $z_{it} > 0$ is an exogenous productivity shock. The first-order conditions from the cost-minimization problem yield producer i's factor demands

$$k_{it} = \alpha \frac{\lambda_{it} X_{it}}{R_t} \tag{8}$$

$$n_{it} = (1 - \alpha - \nu) \frac{\lambda_{it} X_{it}}{W_t} \tag{9}$$

$$l_{it} = \nu \frac{\lambda_{it} X_{it}}{F_t} \tag{10}$$

where

$$\lambda_{it} = \frac{1}{z_{it}} \left(\frac{R_t}{\alpha} \right)^{\alpha} \left(\frac{W_t}{1 - \alpha - \nu} \right)^{1-\alpha-\nu} \left(\frac{F_t}{\nu} \right)^{\nu} \tag{11}$$

is the marginal cost of producing intermediate good i at time t.

In the absence of price rigidities, imperfect information, or anything else that interferes with price-setting, intermediate-good producer i chooses the price P_{it} that maximizes its period-t profits given the demand it faces (5), and thus solves

$$\max_{P_{it}} (P_{it} - \lambda_{it}) \left(\frac{P_{it}}{P_t} \right)^{-\theta_t} \gamma_{it}^{\theta_t - 1} Y_t \tag{12}$$

which yields

$$P_{it} = \frac{\theta_t}{\theta_t - 1} \lambda_{it} \tag{13}$$

a gross mark-up $\frac{\theta_t}{\theta_t - 1} \in (1, \infty)$ of its marginal cost of production λ_{it}. With menu costs, imperfect information, or any other feature that distorts price-setting, intermediate-good producer i will apply a potentially different mark-up ω_{it} to its marginal cost λ_{it}, making its price

$$P_{it} = \omega_{it} \lambda_{it} \tag{14}$$

where the mark-up ω_{it} can differ over time and across producers. It can, depending on the source of the distortions to price-setting, depend on present expectations of future inflation, past expectations of present inflation, expectations of other variables, and the degree of nominal rigidity or uncertainty.

Inserting for the potentially distorted prices (14) into the price aggregator (4), after substituting for the marginal cost of production (11), yields the aggregate price level

$$P_t = \left(\frac{R_t}{\alpha}\right)^{\alpha} \left(\frac{W_t}{1-\alpha-\nu}\right)^{1-\alpha-\nu} \left(\frac{F_t}{\nu}\right)^{\nu} \left(\int_0^1 \left(\frac{\omega_{it}}{\gamma_{it} z_{it}}\right)^{1-\theta_t} di\right)^{\frac{1}{1-\theta_t}} \tag{15}$$

and thus the relative price

$$\frac{P_{it}}{P_t} = \frac{\frac{\omega_{it}}{z_{it}}}{\left(\int_0^1 \left(\frac{\omega_{it}}{\gamma_{it} z_{it}}\right)^{1-\theta_t} di\right)^{\frac{1}{1-\theta_t}}} \tag{16}$$

Substituting this relative price into the demand function for intermediate good i (5), and inserting the resulting equation and the marginal production cost (11), into the factor demands (8), (9) and (10), and aggregating over all intermediate-good producers, we find the aggregate demands for capital, labor and land,

$$K_t = \left(\frac{R_t}{\alpha}\right)^{\alpha-1} \left(\frac{W_t}{1-\alpha-\nu}\right)^{1-\alpha-\nu} \left(\frac{F_t}{\nu}\right)^{\nu} Y_t \frac{\int_0^1 \frac{(\gamma_{it} z_{it})^{\theta_t - 1}}{\omega_{it}^{\theta_t}} di}{\left(\int_0^1 \left(\frac{\gamma_{it} z_{it}}{\omega_{it}}\right)^{\theta_t - 1} di\right)^{\frac{\theta_t}{\theta_t - 1}}} \tag{17}$$

$$N_t = \left(\frac{R_t}{\alpha}\right)^{\alpha} \left(\frac{W_t}{1-\alpha-\nu}\right)^{-\alpha-\nu} \left(\frac{F_t}{\nu}\right)^{\nu} Y_t \frac{\int_0^1 \frac{(\gamma_{it} z_{it})^{\theta_t - 1}}{\omega_{it}^{\theta_t}} di}{\left(\int_0^1 \left(\frac{\gamma_{it} z_i t}{\omega_{it}}\right)^{\theta_t - 1} di\right)^{\frac{\theta_t}{\theta_t - 1}}} \tag{18}$$

$$L_t = \left(\frac{R_t}{\alpha}\right)^{\alpha} \left(\frac{W_t}{1-\alpha-\nu}\right)^{1-\alpha-\nu} \left(\frac{F_t}{\nu}\right)^{\nu-1} Y_t \frac{\int_0^1 \frac{(\gamma_{it} z_{it})^{\theta_t - 1}}{\omega_{it}^{\theta_t}} di}{\left(\int_0^1 \left(\frac{\gamma_{it} z_{it}}{\omega_{it}}\right)^{\theta_t - 1} di\right)^{\frac{\theta_t}{\theta_t - 1}}} \tag{19}$$

respectively.

3 Households

In addition to effortlessly composing final goods, households rent their labor N_t, capital K_t and land L_t to the collectively owned intermediate-good producers in order to provide for consumption C_t and the accumulation of assets: physical capital K_t, money M_t and bonds B_t. Since households are assumed to be identical, aggregation is trivial, so we focus on aggregates directly. Putting money in the utility function u

as a short-cut, each of the continuum of measure one of identical households solves the dynamic problem

$$\max_{C_t,N_t,K_t,B_t,M_t} E_0 \sum_{t=0}^{\infty} \beta^t u\left(C_t, 1-N_t, \frac{M_t}{P_t}\right) \tag{20}$$

subject to

$$K_t + \frac{B_t}{P_t} + \frac{M_t}{P_t} + C_t = \tag{21}$$
$$\frac{W_t}{P_t}N_t + \frac{R_t}{P_t}K_{t-1} + \frac{F_t}{P_t} + (1-\delta)\,K_{t-1} + \frac{(1+\Re_{t-1})\,B_{t-1}}{P_t} + \frac{M_{t-1}}{P_t} + \frac{\Pi_t}{P_t} + S_t$$

given a discount rate $\beta \in (0,1)$, depreciation rate $\delta \in (0,1)$, and initial conditions K_{t-1}, B_{t-1}, M_{t-1} and $\Re_{t-1}$, where $\frac{W_t}{P_t}$ is the real wage, $\frac{R_t}{P_t}$ is the real rental rate of capital, $\frac{F_t}{P_t}$ is the real rental cost of land, $\Re_t$ is the nominal interest rate on bonds, Π_t are profits from the production of intermediate goods, S_t are transfers from the government, and P_t is the aggregate price level, equal to the price of the final good. To simplify, the supply of land is normalized to one.[4]

4 Equilibrium

Exploiting the government budget constraint

$$P_tS_t + P_tG_t = M_t - M_{t-1} + B_t - (1+\Re_{t-1})\,B_{t-1} \tag{22}$$

and that total profits for intermediate-good producers are

$$\Pi_t = \int_0^1 P_{it} z_{it} k_{i,\,t-1}^{\alpha} n_{it}^{1-\alpha-\nu} l_{it}^{\nu} di - R_t K_{t-1} - W_t N_t - F_t \tag{23}$$

households' budget constraints (21) simplify to

$$K_t + C_t + G_t = Y_t + (1-\delta)\,K_{t-1} \tag{24}$$

where

$$Y_t = \int_0^1 \frac{P_{it}}{P_t} z_{it} k_{i,t-1}^{\alpha} n_{it}^{1-\alpha-\nu} l_{it}^{\nu} di \tag{25}$$

[4]The assumption of an inelastic supply of land and the inclusion of this input allows us to obtain an explicit solution for aggregate output. The reason is that the production side only pins down the optimal factor mix, not the levels. However, by fixing the level of one of the inputs, all other levels are pinned down. We let the importance of land converge to zero below.

is the real value of production.[5] Setting aggregate demand for land (19) equal to its inelastic unitary supply yields the aggregate production function

$$Y_t = K_{t-1}^{\alpha} N_t^{1-\alpha-\nu} \frac{\left(\int_0^1 \left(\frac{\gamma_{it} z_{it}}{\omega_{it}}\right)^{\theta_t - 1} di\right)^{\frac{\theta_t}{\theta_t - 1}}}{\int_0^1 \frac{(\gamma_{it} z_{it})^{\theta_t - 1}}{\omega_{it}^{\theta_t}} di} \tag{26}$$

after exploiting that the aggregate demands for factors of production (17)-(19) imply that

$$\frac{R_t}{F_t} = \frac{\alpha}{\nu K_{t-1}} \tag{27}$$

$$\frac{W_t}{F_t} = \frac{1-\alpha-\nu}{\nu N_t} \tag{28}$$

which guarantees an optimal input mix in the production of intermediate goods. Combining these two conditions with the one for the price level (15), yields

$$\frac{R_t}{P_t} = \alpha K_{t-1}^{\alpha-1} N_t^{1-\alpha-\nu} \left(\int_0^1 \left(\frac{\gamma_{it} z_{it}}{\omega_{it}}\right)^{\theta_t - 1} di\right)^{\frac{1}{\theta_t - 1}} \tag{29}$$

$$\frac{W_t}{P_t} = (1-\alpha-\nu) K_{t-1}^{\alpha} N_t^{-\alpha-\nu} \left(\int_0^1 \left(\frac{\gamma_{it} z_{it}}{\omega_{it}}\right)^{\theta_t - 1} di\right)^{\frac{1}{\theta_t - 1}} \tag{30}$$

$$\frac{F_t}{P_t} = \nu K_{t-1}^{\alpha} N_t^{1-\alpha-\nu} \left(\int_0^1 \left(\frac{\gamma_{it} z_{it}}{\omega_{it}}\right)^{\theta_t - 1} di\right)^{\frac{1}{\theta_t - 1}} \tag{31}$$

which are the real rental rates and the real wage. Due to the lack of significance of land as a source of fluctuations, we let ν converge toward zero, so that land is eliminated from the model henceforth.

5 Total factor productivity

Aggregate output is ($\nu \to 0$)

$$Y_t = A_t K_{t-1}^{\alpha} N_t^{1-\alpha} \tag{32}$$

[5] We use the convention that it is capital K_{t-1} that is available to produce in period t, so that intermediate-good producer i is renting $k_{i,t-1}$ units of capital in period t.

where total factor productivity

$$A_t = \frac{\left(\int_0^1 \left(\frac{\gamma_{it} z_{it}}{\omega_{it}}\right)^{\theta_t - 1} di\right)^{\frac{\theta_t}{\theta_t - 1}}}{\int_0^1 \frac{(\gamma_{it} z_{it})^{\theta_t - 1}}{\omega_{it}^{\theta_t}} di} \tag{33}$$

depends on both the level and the dispersion of the productivity shocks γ_{it} and z_{it}, but only on the dispersion in the mark-ups ω_{it}. To see this, note that when all intermediate-good producers i apply the same mark-up ω_t, total factor productivity (33) simplifies to

$$A_t = \left(\int_0^1 (\gamma_{it} z_{it})^{\theta_t - 1} di\right)^{\frac{1}{\theta_t - 1}} \tag{34}$$

independently of the value of ω_t.

Intuitively, increased productivity $z_{it}\gamma_{it}$ for all producers of intermediate goods raises total factor productivity A_t, since more final goods Y_t can be produced with any given (strictly positive) quantities of capital and labor. A higher z_{it} makes capital and labor more efficient in the production of intermediate goods, while a higher γ_{it} raises the amount of final goods that can be produced with a given amount of intermediate goods. A mean-preserving spread of productivity, $z_{i,t}\gamma_{i,t}$, has a positive effect on total factor productivity as a result of inputs flowing from low-productivity to high-productivity intermediate-good producers. This effect is greater the larger the elasticity θ_t, that is, the easier it is to substitute between intermediate goods.

Since producers face the same elasticity θ_t, they should all apply the same mark-up. When they do not, relative prices become distorted, which in turn makes the composition of the final good inefficient, resulting in less of it being produced with any given amounts of capital and labor. The level of the mark-ups has no effect on relative prices, or the composition of final goods, so it has no effect on total factor productivity. The negative impact dispersion in mark-ups has on total factor productivity is larger the smaller the value of $\theta_t \in (1, \infty)$, since this reduces the substitutability between intermediate goods, making productivity drop more as the cost-minimizing mix of these changes in reaction to the distorted relative prices.

Observing the effects nominal rigidities have on total factor productivity empirically promises to be difficult. Productivity is affected by many other factors, such as the development and diffusion of new technologies. In addition, total factor productivity is a key variable that economic theory predicts should impact almost all other variables, including those we might expect to be important in distorting price setting, such as inflation.[6] More importantly, the lack of an accurate measure of the capital stock (and its rate of utilization) reduces the reliability with which Solow residuals estimate total factor productivity.

6 Factor markets

The real rental rate of capital and the real wage are ($\nu \rightarrow 0$)

$$\frac{R_t}{P_t} = \alpha K_{t-1}^{\alpha-1} N_t^{1-\alpha} Q_t \tag{35}$$

$$\frac{W_t}{P_t} = (1-\alpha)\, K_{t-1}^{\alpha} N_t^{-\alpha} Q_t \tag{36}$$

respectively, where

$$Q_t = \left(\int_0^1 \left(\frac{\gamma_{it} z_{it}}{\omega_{it}} \right)^{\theta_t - 1} di \right)^{\frac{1}{\theta_t - 1}} \tag{37}$$

captures the direct impact of dispersion. Without dispersion in mark-ups, we have

$$Q_t = \frac{1}{\omega_t} \left(\int_0^1 \left(\gamma_{it} z_{it} \right)^{\theta_t - 1} di \right)^{\frac{1}{\theta_t - 1}} \tag{38}$$

so in general the value of Q_t does not only depend on the dispersion in the mark-ups, but also on their (average) level.

Increased productivity $\gamma_{it} z_{it}$ for all producers raises total factor productivity A_t, and therefore also tends to raise factor prices, just as a regular positive productivity shock would. Because a mean-preserving spread of productivity $\gamma_{it} z_{it}$ across producers i raises total factor productivity, it also contributes to increase factor prices. In fact, when mark-ups are homogeneous, we have $Q_t = \frac{A_t}{\omega_t}$, so that shocks to (the level or dispersion of) productivity have the same impact on total factor productivity and on factor prices for given levels of capital and labor, just as they would in a model with homogeneous intermediate-good producers. The effect of a mean-preserving spread in productivity across firms is greater the larger is the elasticity of substitution θ_t, just as for total factor productivity.

By leading to an inefficient mix of intermediate goods, dispersion in mark-ups makes capital and labor be used less efficiently in producing final goods, which contributes to lowering the real rental rate and wage.

[6] Monetary policy responding to movements in output spurred by changes in productivity can also hide the impact that variables such as inflation can have on total factor productivity in combination with nominal rigidities.

In addition, this dispersion makes some firms apply mark-ups that are higher, and others apply mark-ups that are lower, than they otherwise would, affecting the size of the average mark-up. This impacts real factor prices because the higher a mark-up an intermediate-good producer applies, the lower its production will be, and the less factors it demands, which tends to reduce factor prices. Whether the effect on real factor prices is positive or negative depends on the skewness of the distribution of the mark-ups, and since firms that apply low mark-ups become larger than those that apply high ones, the distribution needs to be positively skewed for the impact on factor prices to be negative (so that the producers that charge too high mark-ups shrink by more than what those that charge too small mark-ups grow). When the distribution is not positively skewed to a sufficient extent, dispersion in mark-ups can raise factor prices despite lowering total factor productivity. This, combined with elastic supplies of the factors of production can make aggregate output increase as the dispersion in the mark-ups grows, despite that this lowers total factor productivity. An example of this is the inflation-output trade-off that arises in sticky-price models such as that proposed by Calvo (1983). Inflation distorts mark-ups, which reduces total factor productivity, but at the same time those that charge mark-ups that are too low increase their sales so much that total output actually grows. Increasing aggregate output at a time when total factor productivity falls is obviously highly costly in terms of household utility, providing a strong rationale for avoiding inflation. However, with price-stickiness such a rationale would exist even without an inflation-output trade-off, since inflation would still be costly, in terms of temporarily reducing total factor productivity.

Distortions to price-setting that have a uniform effect on the mark-ups of all producers, not generating dispersion, have no effect on total factor productivity, and only affect aggregate output through the quantity of factors employed. Since these can raise or lower the mark-ups, such distortions can, in theory, contribute to either raise or lower aggregate output. By reducing the dead-weight loss of monopolistic competition, distortions to price-setting can actually be beneficial in this case, if they contribute to increasing output. When distortions to price-setting do affect the dispersion of mark-ups, they lower total factor productivity, which always has a negative impact on welfare. Still, the total effect on aggregate output, and factor markets, can go either way. Hence, when dispersion leads to higher output through a lower average mark-up, dispersion can have a positive impact on welfare by reducing the dead-weight loss from imperfect competition. As a result, when distortions tend to raise output by lowering the average mark-up and the extent to which market-power is exerted, it may no be optimal to eliminate these completely.

The impact heterogeneous mark-ups have on total factor productivity A_t and factor prices through Q_t

depend on the dispersion of productivity $\gamma_{it} z_{it}$ and the elasticity of substitution θ_t, both of which can vary over time. As a result, one should not expect the effects of heterogeneous mark-ups to be constant over time (even with constant mark-ups). In particular, when inflation is key in generating the dispersion in the mark-ups, as in sticky-price models, one should not expect the inflation-output relationship to be a stable one, since in theory, even its sign could change over time, as the relative importance of the effects through A_t and Q_t change when θ_t and the dispersion in productivity change. This implies that putting our model, and the relevance of price distortions, to the test empirically by studying output is a futile task.

7 Income shares

According to our model ($\nu \rightarrow 0$), the labor share of income is

$$\frac{W_t N_t}{P_t Y_t} = (1-\alpha) \frac{\int_0^1 \frac{(\gamma_{it} z_{it})^{\theta_t - 1}}{\omega_{it}^{\theta_t}} di}{\int_0^1 \left(\frac{\gamma_{it} z_{it}}{\omega_{it}} \right)^{\theta_t - 1} di} = (1-\alpha) \frac{Q_t}{A_t} \tag{39}$$

which simplifies to

$$\frac{W_t N_t}{P_t Y_t} = \frac{1-\alpha}{\omega_t} \tag{40}$$

when mark-ups are identical across intermediate-good producers. Hence, in general this share depends on both the level and dispersion of the mark-ups, in addition to the dispersion, but not the level, of productivity.[7] The share also depends on the value of α and the elasticity of substitution θ_t (through A_t, Q_t and ω_{it}). The same applies to the income share of capital, which is

$$\frac{R_t K_t}{P_t Y_t} = \alpha \frac{\int_0^1 \frac{(\gamma_{it} z_{it})^{\theta_t - 1}}{\omega_{it}^{\theta_t}} di}{\int_0^1 \left(\frac{\gamma_{it} z_{it}}{\omega_{it}} \right)^{\theta_t - 1} di} = \alpha \frac{Q_t}{A_t} \tag{41}$$

so barred any changes in α, it behaves exactly the same as the income share of labor (39). Whatever income is not used to pay capital and labor goes to profits, so their share is

$$\frac{\Pi_t}{P_t Y_t} = 1 - \frac{\int_0^1 \frac{(\gamma_{it} z_{it})^{\theta_t - 1}}{\omega_{it}^{\theta_t}} di}{\int_0^1 \left(\frac{\gamma_{it} z_{it}}{\omega_{it}} \right)^{\theta_t - 1} di} = 1 - \frac{Q_t}{A_t} \tag{42}$$

[7] When productivity is distributed independently of the mark-ups, the income share of labor is also independent of the dispersion in productivity. Learning-by-doing is one example why the two distributions might not be independent, since firms charging low mark-ups will have larger sales and thereby learn and advance more technologically. Alternatively, firms with high mark-ups have higher profits, which can be used for research and development.

which moves in the opposite direction of the capital and labor shares.

Without distortions to price-setting, the income shares of labor, capital and profits simplify to $\frac{1-\alpha}{\omega_t}$, $\frac{\alpha}{\omega_t}$ and $1 - \frac{1}{\omega_t}$, respectively, where the mark-up is $\omega_t = \frac{\theta_t}{\theta_t - 1}$, so apart from α, the shares would only depend on the level of competition θ_t. When the economy becomes more competitive, producers charge lower mark-ups, reducing the share of income that goes to profits and raising the shares of labor and capital. When the economy becomes less competitive, the process is reversed. Given the discussion on A_t and Q_t above, it should be clear that our model offers no unambiguous prediction as to how the income shares should be affected by distortions to mark-ups, since their impact on Q_t is ambiguous.

8 Income share data

Table 1 shows gross domestic income by type of income, as reported quarterly by the BEA.[8] It lists the average percentage of gross domestic income for each category over the period stretching from the first quarter of 1960 to the third quarter of 2009. Our model has no taxes or subsidies on production, and only three categories of income: compensation of labor, payments to capital and profits. Hence, the mapping between the model and the data is not unambiguous. While it is fairly safe to assign compensation of employees to the labor share and consumption of fixed capital to the capital share, it is not clear how most of the other categories should be allocated. In particular, this applies to net operating surplus, which does not distinguish between pure economic profits and the compensation for the labor and capital that the owners of the enterprises themselves contribute without receiving explicit compensatory payment. The contribution of capital owned and used by the enterprise itself is not specified either. This is a problem because the income shares of labor and capital on one hand, and that of profits on the other, could, according to our model, behave very differently. As a result, the only income share we have a reasonable measure for is that of labor, estimated by the compensation of employees.[9] It is obviously biased downward, since net operating surplus is likely to contain some compensation of labor, but averaging 57.6% of gross domestic income, the compensation of employees contains the bulk of the income share of labor (at least

[8] See NIPA table 1.10 at www.bea.gov. We use the abbreviation IVA for inventory valuation adjustment and CCA for capital consumption adjustment. Our numbers are as reported by the BEA at the end of 2009, but are subject to revisions, especially for the last three years.

[9] NIPA table 1.15, titled "Price, cost and profit per unit of real gross value added of nonfinancial domestic corporate business", provides unit labor costs and profits. However, unit profits are only from current production, and it is unclear exactly what the BEA includes as profits. Because of this, and to make it easier to compare with other countries, we focus on the data from table 1.10 described above. The correlation between the labor share of income computed from tables 1.10 and 1.15 is .85.

Gross domestic income	100.0%
Compensation of employees, paid	57.6%
Wage and salary accruals	48.8%
Supplements to wages and salaries	8.8%
Taxes on production and imports	7.8%
Less: Subsidies	0.4%
Net operating surplus	23.5%
Private enterprises	23.5%
Net interest and misc. payments	5.6%
Business current transfer payments	0.6%
Proprietors' income with IVA & CCA	7.5%
Rental income of persons with CCA	1.7%
Corporate profits with IVA & CCA	8.0%
Taxes on corporate income	3.1%
Profits after tax with IVA & CCA	4.9%
Current surplus of gov. enterprises	0.0%
Consumption of fixed capital	11.6%
Statistical discrepancy	0.5%

Table 1: Gross domestic income by type of income, averages for 1960-2009.

80% by traditional measures).

Figure 1 plots the compensation of employees as a fraction of gross domestic income. While it has remained between .55 and .61, there are fairly long periods where it persistently wandered off from its average of .58. The figure also includes the quarterly rate of inflation, as an annually compounded rate computed from the GDP deflator reported by the BEA.[10] It is clear that the labor share and the rate of inflation tend to move in the same direction. The correlation between the two is .71, which is surprisingly high, especially considering that there appears to be a somewhat non-linear relationship between the two, as is illustrated in figure 2, which plots the income share of labor versus inflation (the line connects contiguous observations). It is interesting to see that the income share of labor was particularly high in the 70s, a decade with widespread price controls that are likely to have significantly distorted price-setting.

According to our model, there are several feasible explanations for the co-movement between inflation and the income share of labor observed in the data. The first is that inflation generates dispersion in mark-ups, thereby reducing total factor productivity A_t and raising the labor share. The second is that inflation reduces mark-ups, making Q_t and the labor share increase. Both of these explanations rely on inflation distorting price setting due to nominal rigidities. Without such rigidities, the observed co-movement can, according to our model, only be due to the rate of inflation and the income share of labor

[10]See NIPA table 1.1.4 at www.bea.gov.

both responding to changes in the degree of competition θ_t, the only variable that affects the labor share in the absence of nominal rigidities.[11] When it increases and the economy becomes more competitive, the labor share increases (by lowering mark-ups ω_{it} across all i). While there is no reason to believe that the rate of inflation should be directly affected by the income share of labor, or the degree of competition, increased competition tends to raise real output, which we do expect to impact inflation, either directly, or indirectly through monetary policy.[12] As a result, variations in the degree of competition could generate a positive co-movement between inflation and the labor share even in the absence of nominal rigidities. However, if this were the case, the co-movement between inflation and the labor share should be weaker than that between inflation and output. The reason is that the shocks typically considered most relevant for business cycles, such as those to productivity, affect output, but not the labor share, and are otherwise indistinguishable from changes in competition.[13] Since we observe the opposite in the data, where the co-movement between inflation and the income share of labor is stronger than that between inflation and output (its level, deviation from trend, or growth rate), we find that inflation reacting to changes in output is not a plausible explanation for the observed co-movement.

Testing whether the observed co-movement between the labor share and the rate of inflation is due to nominal rigidities, or due to both of these reacting to changes in competition, requires data on the overall degree of competition θ_t in the U.S. economy. Since no direct measures are available, we use business bankruptcy filings, total industry capacity utilization, real GDP, total employees in private industries and the real exchange rate as proxies.[14] These are obviously very noisy measures of competition, since they are affected by all sorts of shocks, including those to productivity. However, this is unavoidable, since except for their impact on the income shares, shocks to the degree of competition are indistinguishable from regular productivity shocks in aggregate data.[15] With heterogeneous productivity across firms, changes in the degree of competition even affect total factor productivity.

According to our model, in the absence of nominal rigidities the income share of labor only depends on the degree of competition θ_t and the constant α, which should both be unaffected by inflation (assuming

[11] This assumes that the coefficient α remains constant.

[12] An increase in the labor share does not necessarily mean that total compensation of labor, or wages, increase, since these are also affected by other economic variables, in particular productivity. The same applies for increased competition.

[13] Other examples are shocks to government purchases and the demand for exports.

[14] As part of its Economic Census, the U.S. Census Bureau provides concentration ratios for different sectors, but the survey is only conducted every five years.

[15] Real unit profits from NIPA table 1.15 are sometimes used as an aggregate measure of mark-ups and the degree of competition θ_t. However, according to our model, real unit profits should be perfectly correlated with the income share of labor and capital, with or without nominal rigidities. As a result, it cannot be used to control for changes in the degree of competition and to test for nominal rigidities.

no nominal rigidities). Hence, using the available proxies to control for changes in competition, the rate of inflation should be insignificant when regressing the income share of labor on these and inflation, if nominal rigidities are irrelevant.[16] In the presence of nominal rigidities, it would be natural for all of our proxies of the degree of competition to depend on inflation, so the estimated coefficient, and even its sign, is not a reliable estimate of the relationship between inflation and the income share of labor, since it could be picking up the effect of inflation through the proxies.[17] However, it remains true that without nominal rigidities the coefficient on inflation should be zero, because in this case all the proxies would be independent of inflation.

Since the error with which our proxies measure the degree of competition to a great extent is due to productivity shocks, we should expect the error term of our regression equation to be serially correlated. As usual, we find that a first-order autoregression captures this correlation well. When including this autoregressive component, we use Two-Stage-Least-Squares with the lagged values of the dependent and independent variables as instruments. Otherwise we apply ordinary least squares. As an alternative way to correct for serial correlation, the equations are estimated also in terms of first differences. The results are reported in the columns of table 2. The numbers in parenthesis are the estimated standard deviations (Newey-West HAC for the equations in levels).

Despite being able to explain most of the variation in the income share of labor with our proxies for the degree of competition ($R^2 = .68$, not reported in table), we cannot reject that inflation has an influence. This remains true even when modeling the serial correlation in the residuals as a first-order autoregressive process, which renders all but our bankruptcy filings measure of competition insignificant. Of our proxies for the degree of competition, only the number of employees in private industries and GDP are available from 1960. Bankruptcy filings are available from 1980, the real exchange rate series starts in 1973, while capacity utilization is measured from 1967, so using these greatly diminishes the size of our sample. Because of this, the equations are re-estimated using only the number of employees and GDP as proxies for the degree of competition. The last two columns of the table provide the results the estimates in terms of log-differences. As for the previous specifications, the rate of inflation remains significant.

[16]The logarithm was applied to all variables in the regression equations. For the GDP deflator we use the logarithm of the gross rate of inflation. For the equations in terms of levels, the number of employees in private industries and real GDP were linearly detrended. In the equations in terms of changes, the log-difference was applied also to the explanatory variables. Source of data.

[17]As an example, with nominal rigidities employment would depend on the rate of inflation, so when we use it as a proxy for the degree of competition, the coefficient on the rate of inflation would not only be capturing the direct effect of inflation on the labor share, since it would also be affected by the impact inflation has on employment.

	level	level	level	level	Δ	Δ
const	.877 (.283)**	.137 (.606)	−.573 (.003)**	−.594 (.010)**	.000 (.001)	.001 (.000)**
gdpdefl	.390 (.076)**	.564 (.169)**	.591 (.062)**	1.180 (.308)**	−.094 (.042)*	−.072 (.028)*
privempl	.333 (.071)**	.157 (.148)	.191 (.071)**	.248 (.108)*	.259 (.106)*	.374 (.068)**
gdp	.047 (.103)	.154 (.194)	−.031 (.079)	−.349 (.207)	−.262 (.091)**	−.369 (.051)**
caputil	−.319 (.052)**	−.219 (.100)*	-	-	−.085 (.052)	-
realex	−.052 (.017)**	−.017 (.036)	-	-	−.024 (.017)	-
bankrup	.020 (.004)**	.034 (.012)**	-	-	−.001 (.003)	-
ar(1)	-	.569 (.113)**	-	.687 (.067)**	-	-
R^2	.79	.82	.59	.62	.20	.22
obs	119	118	199	198	118	199

Table 2: Regressions of the income share of labor on inflation and proxies of competition, all in logarithms.

While the positive co-movement observed empirically between inflation and the income share of labor is consistent with the existence of an inflation-output trade-off, it is not necessarily implied, since it can alternatively be explained by inflation reducing total factor productivity A_t, and thus having a negative impact on output. If one believes nominal rigidities make inflation distort relative prices, then inflation has a negative impact on total factor productivity, which means that in order for an inflation-output trade-off exists, inflation should be associated with increased factor use. Of course, this is dfficult to detect empirically, since economic theory predicts that inflation and factor use should both depend on key economic shocks such as those to productivity.[18]

Intuitively, one might expect inflation to be positively related to mark-ups, since higher mark-ups should arguably lead to higher prices. This implies that without nominal rigidities, the income share of labor should be negatively related to inflation, contrary to what we observe in the data. However, this intuition ignores the fact that with flexible factor prices, the production costs that are being marked up decrease with the level of mark-ups, so that higher mark-ups do not necessarily result in higher prices. The fact that inflation is positively correlated with the income share of labor implies that rigidities in factor markets alone cannot explain the data, since then the correlation should be negative.

[18]The same applies to factor prices and the total payments to the factors of production.

	Mean	% < 0	Mean*	SD*	AC	Corr lshare gdpdef*	Corr lshare ann. gdpdef*
AU	5.5	13.6	6.7	4.8	.48	.54	.75
CA	4.4	7.2	4.9	3.6	.68	.37	.50
FR	3.8	2.4	3.9	3.6	.93	.87	.90
IT	5.5	3.5	5.8	4.7	.67	.75	.86
JP	.3	50.9	2.0	1.8	.35	.00	-.32
UK	6.1	6.5	6.7	6.1	.60	.60	.60
US	3.7	.5	3.7	2.5	.87	.71	.74

Table 3: Inflation statistics as measured by the seasonally adjusted GDP deflator compounded annually.

9 International data

The OECD collects quarterly national income account data for more than thirty countries.[19] Unfortunately, for most of these it has less than twenty years of observations. For Australia and the UK it goes all the way back to 1960 (and earlier), just as our U.S. data. For Canada it starts in 1961, for France in 1978, Japan in 1980 and Italy in 1981. For the remaining countries the series start anywhere between 1988 and 2000, so these were discarded for having too few observations. The data, which is seasonally adjusted, is plotted in figure 3. The first column plots the rate of inflation (computed from the GDP deflator) and the income share of labor for each of the countries. The second column has the same two variables, but plotted in a scatter diagram.

For France and Italy the co-movement between inflation and the income share of labor appears to be stronger than in the U.S., which is confirmed in table 3, which reports basic statistics. The co-movement is weaker for the remaining countries, especially in Japan, where it is nonexistent, but Japan has also experienced much less inflation than the other countries. Comparing across countries, we find that the rate of inflation is more persistent in the U.S. than in all the other countries in our sample, except for France. This is relevant because inflation could distort prices gradually over time. Hence, the distortions and income share of labor might be large in a quarter not because inflation was high in that quarter, but because it was high just prior to that. In order to account for this, the third column in figure 3 plots the income shares of labor for different countries versus their rates of inflation over the last four quarters, instead of just the contemporaneous quarter.[20] It shows, and the numbers in table 3 confirm, that this

[19]See www.sourceoecd.org/database/OECDStat. The data is subject to retroactive revisions. The numbers used are the ones reported at the end of 2009. For the U.S. we keep using the data from the BEA throughout.

[20]If nominal rigidities make inflation distort price setting gradually over time, the current level of distortions and income share of labor would not only depend on past inflation, but also on anticipated future inflation. The reason is that if price-setters adjust prices gradually, they will adjust for expected future inflation ahead of time, just as they adjust for inflation retroactively over time. Unfortunately, measures of inflation expectations are difficult to come by.

Country	const	gdpdefl	civempl	gdp	R^2	obs
AU	.003 (.001)*	−.088 (.018)**	.214 (.187)	−.462 (.095)**	.17	170
CA	.004 (.001)**	−.075 (.017)**	.385 (.106)**	−.648 (.073)**	.32	193
FR	.003 (.001)**	−.020 (.038)	.902 (.225)**	−.933 (.109)**	.38	125
IT	.001 (.001)	−.050 (.024)*	.266 (.145)	−.683 (.121)**	.25	113
JP	.003 (.001)**	−.071 (.035)*	.883 (.240)**	−.755 (.079)**	.46	117
UK	.003 (.001)**	−.098 (.015)**	.595 (.193)**	−.657 (.082)**	.37	161
US	.001 (.000)**	−.072 (.028)*	.374 (.068)**	−.369 (.051)**	.22	199
All	.002 (.000)**	−.084 (.007)**	.438 (.055)**	−.559 (.031)**	.26	1078

Table 4: Regression of income share of labor on inflation, employment and real GDP, all in log-differences.

raises the correlation between the income share of labor and inflation, more so the less persistent a country's inflation is. The only exception is Japan, for which the correlation is negative.

The impact inflation has on the income share of labor with nominal rigidities can depend on the degree of competition θ_t and the dispersion in productivity, both of which can differ over time and across countries. As a result, there is no reason to expect the effects to be homogeneous across countries. However, as is reported in table 4, we find that when regressing the income share of labor on inflation, employment and real GDP, all in terms of log-differences, the results are surprisingly similar across countries. In fact, one can only reject homogeneity in terms of the coefficients associated with GDP, the ones for the constant terms, inflation and employment are not different to a statistically significant degree (tested individually or jointly).[21] Despite controlling for changes in the degree of competition through real GDP and employment, the rate of inflation is statistically significant for all countries except France.[22] This might be due to the high inflation persistence in that country, and the fact that we only have 125 observations for it. Pooling the observations for all the countries, exploiting the similarities across these to improve our estimates by increasing the sample size, we find that inflation is statistically significant for the group as a whole.[23]

[21] Employment is measured by civilian employment with two exceptions. For France the closest we could find was total employment. For the U.S. we continue using employees in private industries.

[22] The real exchange rate, the only other measure of competition readily available was not statistically significant for any of the countries in our sample.

[23] While we reject that the coefficient on real GDP is the same for all the countries in our sample, we include it as a common factor in order to simplify the table. Keeping these as cross-section specific coefficients yields almost identical numbers for the common coefficients, while the ones for GDP are very close to those estimated with the unpooled data, which are reported above in the table.

10 Conclusions

We show that in order for an inflation-output trade-off to exist due to nominal rigidities that make inflation distort price-setting, such as menu costs, sticky prices, sticky information and monetary misperceptions, the income share of labor should be positively related to the rate of inflation. We find that this is indeed the case in the U.S. and the 6 other OECD countries for which data goes back at least 25 years. While one can imagine alternative explanations of the observed co-movement based on endogenous money, or policy reacting to output, these are not plausible, since then we should see a stronger co-movement between inflation and output than between inflation and the income share of labor, the opposite of what we find in the data. The reason is that most shocks typically considered important for business cycles would affect inflation and output, but not the income share of labor.

While the observed co-movement between the income share of labor and inflation is consistent with the existence of an inflation-output trade-off, it is not necessarily implied. The reason is that it could be explained equally well by nominal rigidities that make inflation distort price setting without leading to higher output. In fact, our model predicts that changes in the degree of competition and the dispersion in technology across producers would not only alter the relationship between inflation and output, but could even reverse its sign. This is because such changes affect the relative strength of the two channels through which inflation distorts price setting with nominal rigidities, and these pull in opposite directions. On one hand, inflation can distort relative prices, which pushes the cost-minimizing mix of goods away from the efficient mix, thus reducing total factor productivity and the amount of output that can be produced. On the other hand, inflation can lower the mark-ups that buyers end up paying, thus raising output by reducing the dead-weight loss from imperfect competition. Since both of these effects push the income share of labor in the same direction, the impact of nominal rigidities should be easier to detect there than in output or factor use.

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Figure 1: Income share of labor and rate of inflation in U.S.

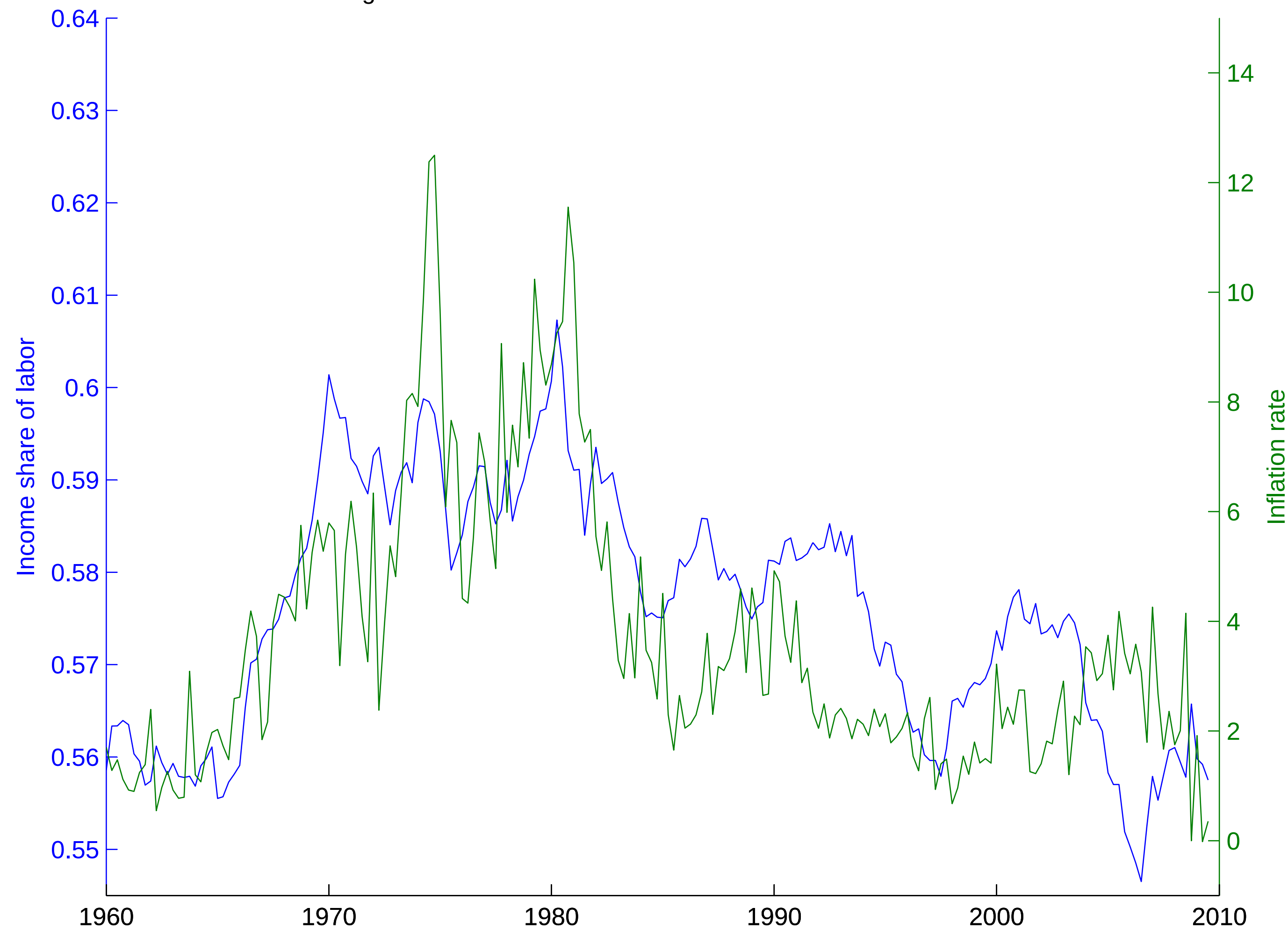

Figure 2: Income share of labor vs rate of inflation in U.S.

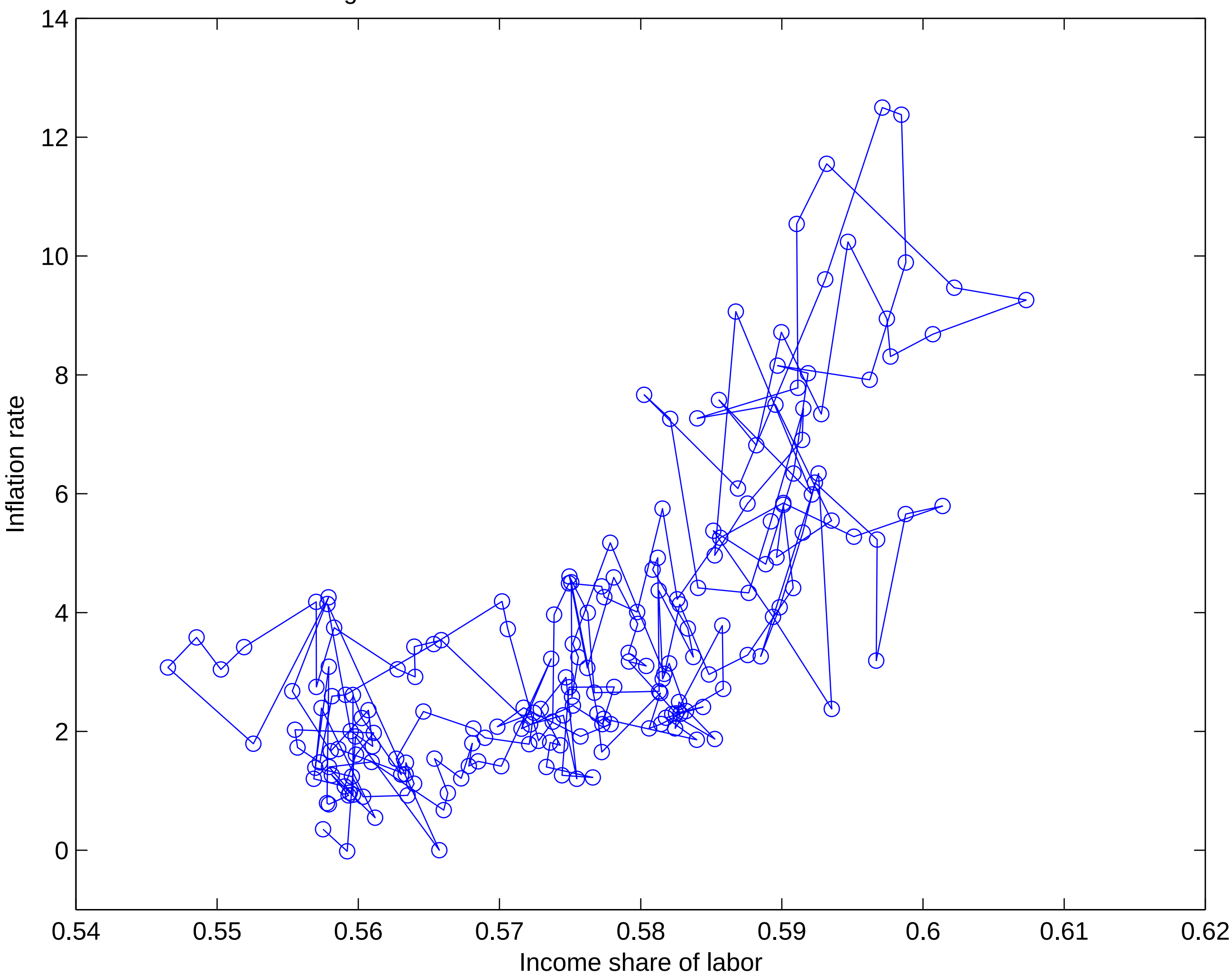

Figure 3: Income share of labor and rate of inflation, SA (quarterly, annual)