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The Long-Run Relationship Between Inflation and the Markup in the U.S.

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Abstract

This paper examines the long-run relationship between inflation and a new measure of the price-marginal cost markup. This new markup index is derived while accounting for labor adjustment costs, which a large number of the papers that estimate the markup have ignored. We then examine the long-run relationship between this markup measure, which is estimated using U.S. manufacturing data, and inflation. We find that decreases in the markup that are associated with a percentage point increase in inflation are much smaller than previous studies have found.

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1 Introduction

The models of Russell et al. (2002) and Chen and Russelll (2002) suggest that higher inflation is associated with a lower markup, which is empirically confirmed by Banerjee et al. (2001) and Banerjee and Russell (2005). However, the markup measures used in these papers involve the assumption that real unit labor costs (equivalently the labor income share) can proxy for marginal cost. Mazumder (2010a) argues that real unit labor costs cannot be used to proxy for marginal cost since this measure is derived under the assumption that labor has no adjustment costs.

Furthermore, a great deal of work has extended Hall (1986, 1988)'s markup methodology, which has become the workhorse when it comes to estimating the markup.[1] The problem with this methodology, is that it also assumes marginal cost can be measured without accounting for labor adjustment costs. Mazumder (2010b) proposes a solution to this problem by estimating marginal cost in a manner inspired by Bils (1987). In particular, marginal cost is estimated by varying the number of hours worked by employees, while accounting for the fact that wages must be written as a function of hours. This new marginal cost expression is estimated for the U.S. manufacturing sector, which then in turn allows us to derive a new markup index.

Given this new markup index, we then examine its long-run relationship with inflation. Following the lines of Banerjee et al. (2001) and Banerjee and Russell (2005), we estimate the inflation-markup relationship using a cointegrating regression. The results suggest that a statistically significant negative relationship does indeed exist between inflation and the markup, which is in keeping with previous findings.

However, Banerjee and Russell (2005) argue that the decrease in the markup associated with a percentage point increase in inflation is similar under alternative markup measures, which we find not to be true. Specifically, the decrease in the markup associated with a percentage point increase in inflation is about three times larger with the real unit labor cost markup as it is with the new markup measure we develop in this paper. This suggests that the impact of inflation on the markup is much less severe than previous research has suggested, and that this conclusion is highly dependent on what measure of marginal cost is used.

2 Existing Markup Methodology

The seminal method that is used to estimate the markup follows Hall (1988) who estimates the markup, μ, as: $\mu = P/MC^n$, where P is the price level and MC^n is nominal marginal cost. Therefore to estimate μ, one needs a specification for marginal cost, for which Hall uses:

$$MC^n = \frac{W\Delta L + R\Delta K}{\Delta Y - \theta Y} \tag{1}$$

where L is labor input, K is capital stock, W is the wage rate, R the rental price of capital, Y is output, and $-\theta Y$ is an adjustment to output by the amount in which output would have risen in the absence of more capital or labor. The rationale behind this specification

[1] Several extensions to the Hall framework exist, such as Domowitz et al. (1988).

of marginal cost is that we can examine the changes of the inputs of production, namely L and K, while assuming that these factors are paid a fixed price of W and R respectively.

The problem with this is that labor input really should be thought of as the product of the number of employees (N) and the average number of hours they work (H), giving $L = NH$. However Oi (1962) argued that employment has adjustment costs such as recruitment and training costs, while Mazumder (2010a) argues at length that hours can only be varied if wages are also a function of hours. This means that labor adjustment costs are present both with varying employment (recruitment and training costs) and with varying hours (overtime). Thus the use of $W\Delta L$ in (1) assumes that labor can be costlessly adjusted at a fixed wage rate. In other words by using $W\Delta L$ all forms of labor adjustment costs are ignored, which is not reasonable given the large prevailing literature that examines the nature of such adjustment costs.[2]

3 A New Measure of the Markup

3.1 Estimation Methodology

Fortunately we can improve upon the measurement of marginal cost while still accounting for adjustment costs by following an idea proposed by Bils (1987). Specifically we can examine the cost of changing output along any one margin while holding fixed all other inputs at their optimal levels, assuming that firms optimally minimize their costs.[3] Since varying employment necessitates modeling adjustment costs, it is more straightforward therefore to estimate marginal cost by varying the number of hours worked:

$$MC^n = \frac{dCosts}{dY} = \left(\frac{\partial Costs}{\partial H}\right)\left(\frac{\partial H}{\partial Y}\right)|Y^*, H^*, N^* \tag{2}$$

where Y is output, and '*' terms denote optimal levels. To simplify (2) further, we use the same production function as Hall (1988) with the exception that labor is decomposed into employment and hours: $Y = AK^\alpha(NH)^{1-\alpha}$. We also use the same cost function as in Hall (1988), except we also recognize that wages must be a function of hours: $Costs = W(H)NH$, where $W(H)$ is the nominal average hourly wage rate.[4] Also note that RK is omitted from the cost function since we assume K does not vary with respect to H. We can omit K in such way based on the Bils (1987) assumption that marginal cost can be measured by varying only one factor of production, holding fixed all other inputs at their optimal levels.[5] Using these production and cost functions, (2) then simplifies to:

$$MC^n = \frac{1}{1-\alpha}\left(\frac{NH}{Y}\right)[W(H) + W'(H)H] \tag{3}$$

[2] Not to mention the problems of ignoring capital adjustment costs when writing $R\Delta K$.

[3] This is not the only way to measure marginal cost while accounting for adjustment costs, but we find it to be the simplest yet most powerful method.

[4] Many researchers, such as Lewis (1969), have demonstrated that wages must be a function of hours if employment is quasi-fixed.

[5] The relaxation of this assumption is something that future research may wish to examine.

Mazumder (2010a) argues that (3) collapses to unit labor costs when $W'(H) = 0$, which implies that (3) is a more generalized expression for marginal cost than the commonly used labor income share.

Finally we use the same specification for $W(H)$ as Mazumder (2010a) which is: $\overline{W}H + p\overline{W}V$, where $\overline{W}$ is the straight-time part of the wage rate, p is the overtime premium paid on top of $\overline{W}$ for V overtime hours per worker. Therefore the average hourly wage rate is $W(H) = \overline{W}[1 + p\nu(H)]$, where $\nu(H) = V/H$ is the ratio of overtime hours to average hours worked, which must be a function of the number of regular hours worked. Thus we can compute $W'(H)$ to simplify (3) to:

$$MC^n = \frac{1}{1-\alpha}\left(\frac{NH}{Y}\right)\overline{W}[1 + p(\nu(H) + H\nu'(H))] \tag{4}$$

3.2 Overtime Hours Function

To estimate (4) we must first estimate the $\nu(H)$ function, which in turn requires data on overtime hours and overtime premia. For the U.S., reliable overtime data is available only for the manufacturing industry, hence we focus on estimating the markup for this sector instead of approximating for overtime hours for non-manufacturing sectors.[6]

We take quarterly manufacturing data from the Bureau of Labor Statistics for V and H from 1960 to 2007. To estimate the $\nu(H)$ function, we follow Mazumder (2010a) who regresses ν on H and various powers of H using OLS with robust standard errors.[7] This is similar to Bils (1987), with the main difference that Bils estimates $\frac{dV}{dH}$ instead of $\nu(H)$, where we find the latter to be the more intuitive function to estimate. A subset of the results of these regressions (linear and quadratic) can be seen in Table 1, where we select the specification with the highest $\overline{R}^2$. This suggests that the quadratic specification of $\nu(H)$ works best: $\nu(H) = a + bH + cH^2$, from which we can use our estimates of b and c to compute a series for ν' using: $\nu'(H) = b + 2cH$. Bils (1987) also adds higher powers of H to his specification, but we find this reduces the fit of the regression line. However the specification of $\nu(H)$ turns out not to be of crucial importance in this paper; it is the fact that $\nu'(H) \neq 0$ which is vital since this means that (4) does not reduce into real unit labor costs.[8]

3.3 The New Markup Index

We can now estimate the expression for nominal marginal cost from (4), where data on variables are taken from the BLS and Bureau of Economic Analysis, which in turn allows us to derive a new measure of the markup:

$$\mu^m = \frac{P^m}{MC^{n,m}} \tag{5}$$

[6]Such approximations are very problematic, particularly when it comes to measuring overtime hours for salaried workers.

[7]Where ν and H are stationary according to unit root tests.

[8]Results in this paper are robust to the linear and cubic specification of $\nu(H)$ also.

where manufacturing variables are denoted by an 'm' superscript. Using the new nominal marginal cost series, and taking P^m from sectoral GDP price deflator data from the BEA, we can now estimate a series for μ^m, which can be seen in Figure 1.[9]

Two noteworthy features appear from this new markup series. First, the markup has noticeably decreased in trend from 1960 to 2007, falling by over 20 percent. This suggests that the degree of domestic market power in U.S. manufacturing has fallen considerably over the past fifty years. Second, the markup is countercyclical, since it rises during each NBER recession (shaded bars) and falls during periods of expansion. For more rigorous evidence of this, we regress the HP detrended log of the markup on a measure of the business cycle, time trends, and a constant. These results can be seen in Table 2, where the coefficient on each business cycle measure is highly negative and significant, indicating countercyclicality.

Finally, in addition to computing markups at the manufacturing level, we also estimate the series for the durable goods and nondurable goods sectors using the same techniques and data sources as above. These series can be seen in Figure 2.

4 The Long-Run Relationship Between Inflation and the New Markup Index

Banerjee et al. (2001) argue that the long-run relationship between inflation and the markup can be estimated by the following equation:

$$\mu_t = q - \lambda \pi_t \tag{6}$$

where q is the 'gross' markup, π_t is inflation, and λ can be thought of as the inflation cost coefficient. Our goal is to estimate the long-run relationship in (6) using the new markup index[10] as well as a markup that is computed assuming that marginal cost can be approximated by unit labor costs, as is done in Banerjee et al. (2001).[11] We will estimate these relationships using two measures of annualized quarterly inflation: one with the GDP deflator as the price index, and one with the CPI price index instead. Finally we will also estimate (6) for the durable and nondurable goods sectors as well.[12]

Before we can estimate these relationships, we first conduct unit root tests to check for stationarity, the results of which can be seen in Table 3. First we conduct traditional augmented Dickey-Fuller tests, where lag length is determined by the AIC criterion with a maximum lag length of four. Given the potential low power of ADF unit root tests, we also reinforce the exercise by computing Elliott et al. (1996) unit root tests (ERS test), again imposing the same lag length criteria.[13] The results from the table show that all variables, except for the nondurable sector markup and inflation, are non-stationary (and in fact are integrated of order one).

Therefore, to estimate (6) requires a cointegrating regression between the I(1) variables.

[9] This markup measure is in index form since prices are obtained in index form and not levels.

[10] Assuming that the new manufacturing markup variable is a crude proxy for the economy-wide markup.

[11] See Mazumder (2010a) for derivation of unit labor cost proxy for marginal cost.

[12] Where durable and nondurable GDP price deflators are used (BEA data).

[13] With AR spectral OLS estimation.

We do this by using dynamics OLS (DOLS), as detailed in Stock and Watson (1993). DOLS involves estimating a traditional OLS regression between non-stationary variables, but then augmenting it with leads and lags of the first differences of the independent variables:

$$\mu_t = q - \lambda\pi_t - \sum_{i=-k}^{k} \delta\Delta\pi_{t-i} + \varepsilon_t \tag{7}$$

The coefficient estimates of λ obtained in this regression are now superconsistent (Stock (1987)), since the DOLS technique eliminates the effects of regressor endogeneity on the distribution of the least squares estimator.[14]

The results from estimating the long-run relationship between the markup and inflation can be seen in Table 4. We obtain a positive and significant λ in all cases, which confirms the long-run negative relationship that exists between the markup and inflation. We also confirm the results of Banerjee et al. (2001), where the markup that is computed using unit labor costs produces $\lambda \approx 7$. Since a percentage point increase in annual inflation is equivalent to an increase in π of 0.25 per quarter, we divide the estimate of λ by four to determine the decrease in the markup associated with a single percentage point increase in inflation. Thus with the unit labor cost markup, the markup decreases by 1.8 to 1.9% when inflation rises by a percentage point.

However the magnitude of the decrease in the markup is substantially smaller–0.6 to 0.7%–when the new markup measure which accounts for labor adjustment costs is used. Moreover these smaller magnitudes can also be discerned when examining the markup-inflation relationship for the durable and nondurable goods sectors as well. Therefore when the markup is measured while accounting for adjustment costs, we find that the markup responds far less to an increase in inflation than it does under the unit labor cost case. Thus Banerjee and Russell (2005)'s conclusion that magnitude of λ is robust to alternative markup measures does not hold, which means more serious attention must be paid to estimating the markup before examining its long-run relationship with inflation.

5 Conclusion

Previous attempts to estimate the price-marginal cost markup have tended to suffer from two related problems: either the markup is computed using unit labor costs as the proxy for marginal cost, or the markup is estimated based on Hall (1988), which ignores entirely the idea of adjustment costs. In particular both of these methods assume that labor can be costlessly adjusted at a fixed wage rate.

Once we recognize the inapplicability of this assumption, we can improve upon the measurement of marginal cost using the framework of Bils (1987), which is empirically applied by Mazumder (2010a). From this we are then able to derive a new markup index using U.S. manufacturing data.

Using this new markup index, we examine its long-run relationship with inflation. We find that a negative and significant relationship does exist, just as the existing literature

[14]We select a value of $k = 8$ for this paper, and also verify the existence of cointegration by finding the residuals in (7) to be stationary.

argues, but the magnitude of the inflation cost coefficient is starkly different from what other authors have argued. Specifically, the decrease in the markup associated with a percentage point rise in inflation is about a third of the magnitude with the new markup measure as it is with the unit labor cost measure of the markup. Thus, the impact of inflation on the price-marginal markup appears to be less strong than previously thought. Moreover, the Banerjee and Russell (2005) conclusion that the magnitude of the inflation cost coefficient is invariant to the measure of the markup appears not to hold, which is something that future research must address.

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Figure 1: New Markup Index for U.S. Manufacturing

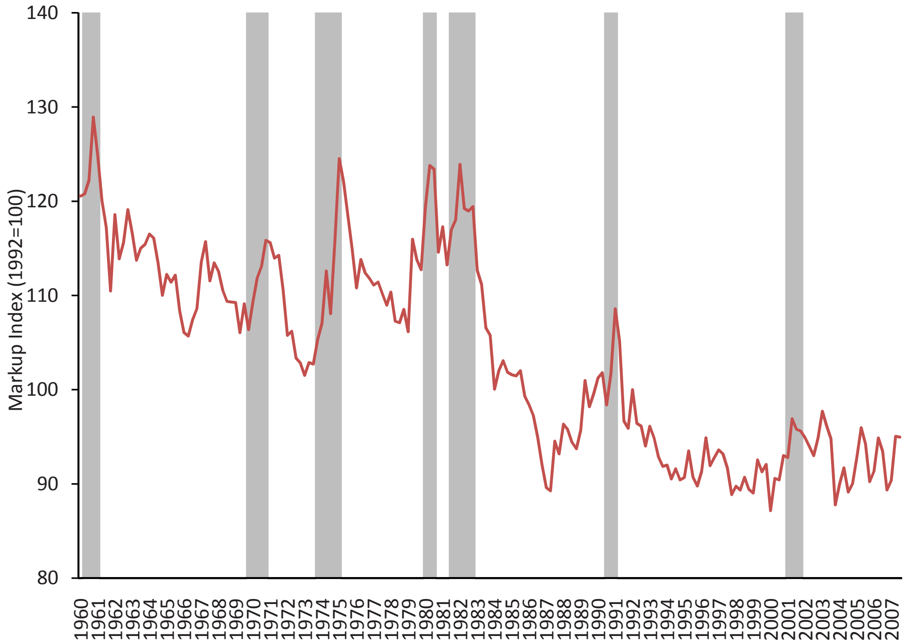

Figure 2: Durables and Nondurables Markup Indexes

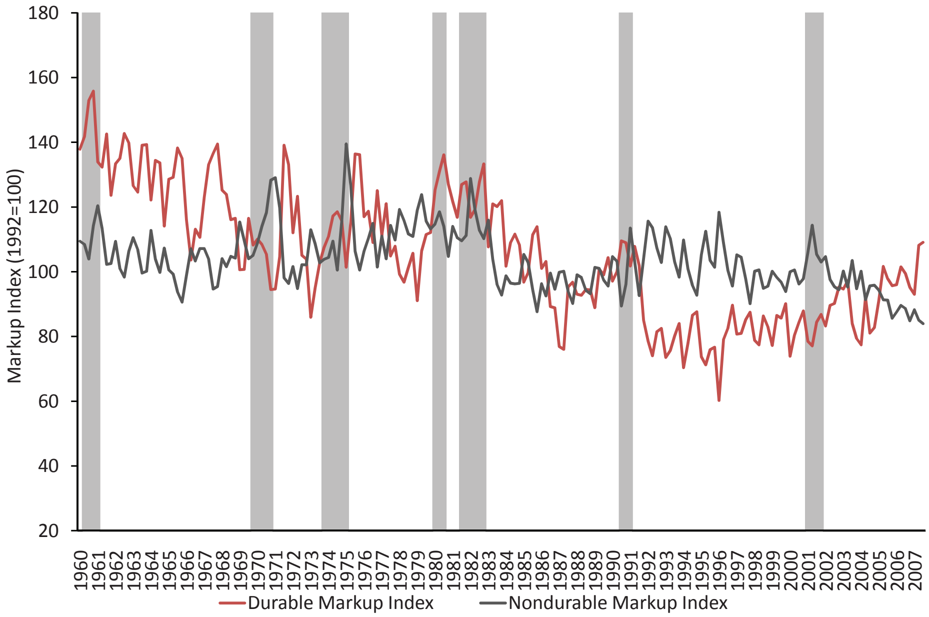

Table 1: $\nu(H)$ Regressions

	$\nu(H) = a + bH$		$\nu(H) = a + bH + cH^2$		
	a	b	a	b	c
Coefficient Standard Error	-.9760154 (.0264964)***	.0264254 (.0006491)***	8.396427 (.949713)***	-.4361621 (.0469388)***	.0057049 (.0005796)***
$\overline{R}^2$	0.8917		0.9228		

Note:'***' denotes rejection of the null hypothesis at the 1% significance level.

Table 2: Cyclicality of Manufacturing Markup

$\mu_t^m = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \alpha_3 t^3 + \alpha_4 Cycle_t$		
$Cycle$:	y_t	h_t
α_0	-0.0017 (.0091)	0.0023 (.0134)
α_1	0.0001 (.0004)	-0.0001 (.0005)
α_2	-8.86e-07 (4.78e-06)	2.62e-07 (5.83e-06)
α_3	3.03e-09 (1.64e-08)	-7.09e-11 (1.91e-08)
α_4	-1.3895 (.2215)***	-5.4173 (.5646)***
$\overline{R}^2$	0.1962	0.2799

Note: OLS estimation is conducted using a Cochrane-Orcutt AR(1) correction to adjust for serial correlation. Two business cycle measures are used: the output gap y_t (HP detrended log output) and an 'hours gap' h_t (HP detrended log of non-farm private sector hours of employment.

Table 3: Unit Root Tests

	ADF		ERS	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend
GDP Deflator Inflation	-2.2502	2.5470	3.8109	11.9701
CPI Inflation	-2.6560	-2.7382	3.9377	9.5817
Durables GDP Deflator Inflation	-1.9856	-2.8660	3.2879	7.3608
Nondurables GDP Deflator Inflation	-4.9752*	-5.0667*	0.9601*	3.0772*
New Manufacturing Markup	-2.6764	-3.9231*	19.2065	6.2330
Unit Labor Cost Markup	-1.8280	-3.3902	52.1949	5.8419
Durables Markup	-2.9073*	-3.7712*	18.3345	6.0977
Nondurables Markup	-3.4965*	-4.2553*	1.1199*	2.4615*

Note: Table reports test statistics from unit root tests. ADF test has a null of a unit root, thus rejection (test statistic smaller than critical value) implies stationarity. The 5% critical value is (approximately) -2.87 for an intercept only and -3.43 for an intercept and trend. The ERS test also has a null of a unit root with 5% critical values of approximately 3.16 (intercept only) and 5.66 (intercept and trend), where rejection occurs when the test statistic is again smaller than the critical value. '*' denotes rejection of the null hypothesis at the 5% significance level.

Table 4: The Long-Run Relationship Between Inflation and the Markup

Measure of Inflation	Measure of Markup	Long-Run Relationship	$\overline{R}^2$	Decrease in the Markup associated with a 1 percentage point increase in inflation
GDP Deflator	New	$\mu_t = -9.2376 - 2.9190\pi_t$	0.3586	0.73%
CPI	New	$\mu_t = -9.3458 - 2.3454\pi_t$	0.3032	0.59%
GDP Deflator	ULC	$\mu_t = -1.9720 - 7.6864\pi_t$	0.1525	1.92%
CPI	ULC	$\mu_t = -1.8328 - 7.2499\pi_t$	0.1848	1.81%
Dur. GDP Defl.	Dur.	$\mu_t = -9.8822 - 3.1047\pi_t$	0.1732	0.78%
Nondur. GDP Defl.	Nondur.	$\mu_t = -9.7577 - 1.7016\pi_t$	0.1868	0.43%

Note: Relationship between the markup and inflation is estimated using DOLS: $\mu_t^m = q - \lambda\pi_t - \sum_{i=-k}^{k} \delta\Delta\pi_{t-i} + \varepsilon_t$. Coefficients of leads and lags are not reported in the results. Since nondurables inflation and the nondurable markup are stationary, we can also estimate this equation using OLS: $\mu_t = -10.1237 - 0.7173\pi_t$, where both coefficients are significant at the 5% level. Furthermore, the coefficients q and λ are statistically significant in every regression in this table at the 5% level.