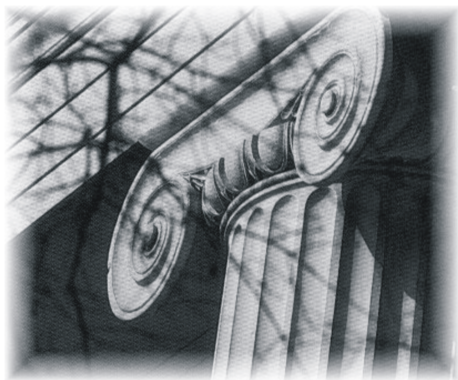
THE UNIVERSITY OF ALABAMA

ECONOMICS, FINANCE AND LEGAL STUDIES

WORKING PAPER SERIES



Working Paper No. 07-07-01

THE PRICE OUTPUT CORRELATION AND THE VARIANCE OF OUTPUT

James P. Cover and Paul Pecorino

Culverhouse College of Commerce and Business Administration
The University of Alabama

July 2007

The Price – Output Correlation and the Variance of Output*

James P. Cover and Paul Pecorino
Department of Economics, Finance and Legal Studies
University of Alabama
Box 870224
Tuscaloosa, AL 35487

Abstract

Using data from Backus and Kehoe (1992) we establish the existence of a positive relationship between the price–output correlation and the variance of output. This is consistent with the idea that reductions in the magnitude of aggregate demand shocks have been the dominant cause of changes in the price-output correlation across countries and across time. By contrast, changes in the magnitude of aggregate supply shocks would impart a negative relationship between the price–output correlation and the variance of output. We also consider and rule out the possibility that a steepening of the aggregate supply curve is the cause of the negative price-output correlation in the postwar era. In the postwar period the variance of output and the price-output correlation both fell compared to the pre-WW II period. We argue that both these changes are likely the result of a more effective monetary policy.

*We would like to thank Kent P. Kimbrough and Junsoo Lee for providing helpful comments on the paper.

1. Introduction

By now it is well known that the price–output correlation has been negative in the United States in the postwar period.[1] In fact, depending upon how the correlation is calculated, it is negative either in eight of the ten countries analyzed by Backus and Kehoe (1992) or in all ten.[2] A crucial question, however, concerns the interpretation of a negative price–output correlation. For example, Kydland and Prescott (1990) and Cooley and Ohanian (1991) argue that the negative price-output correlation found in the data calls into question the relevance of demand driven models. By contrast, the work of Lucas (1994), Chatterjee (1999) and Cover and Pecorino (2003) suggests that a negative price-output correlation can emerge from an effective monetary policy. Since the price-output correlation has varied considerably across countries and time, changes in it are accompanied by changes in other properties of the data, for example changes in the variance of output. This paper shows that the relationship between the price-output correlation and the variance of output can be used to draw important inferences both about the true nature of the macroeconomy and the ability of an effective monetary policy to stabilize output.

Using the statistics reported by Backus and Kehoe (1992), this paper presents both a graphical and a panel data analysis that establishes the existence of a robust, positive relationship between the price-output correlation and the variance of output. Furthermore, given its robustness, a positive relationship between the price-output correlation and the variance of output appears to be an empirical regularity that any useful macroeconomic model should be able to explain. The paper then shows, using a parsimonious macroeconomic model, that the observed

[1] See also Cover and Hueng (2003), Pakko (2000), and Wolf (1991) for evidence that the sign of the price-output correlation has changed. Cover and Huang also provide a useful summary of empirical studies on the price-output correlation.

[2] Using what we call the filtered data, during the postwar era, the correlation is essentially zero for Germany (.01) and weakly positive for Canada (.12), but negative in the other eight countries. When calculated in a different way (what we call the growth rate data below), the correlations computed by Backus and Kehoe are negative for all 10 countries in the postwar era.

positive relationship between the price-output correlation and the variance of output is most likely the result of changes in the variance of the aggregate demand shock across time. Finally, we argue that monetary policy plays a key role in explaining changes in the variance of aggregate demand shocks across time, and that the observed reductions during the postwar era of both the variance of output and the price-output correlation are the result of improvements in the implementation of monetary policy.

Roughly speaking, a fall in the price-output correlation over time suggests that aggregate supply shocks have become relatively more important than aggregate demand shocks as a source of output fluctuations.[3] A simple way to look at this is to presume that the decline in the price-output correlation is the result of an increase in the ratio of the variance of aggregate supply shocks to the variance of aggregate demand shocks. If the increase in this ratio is primarily the result of an increase in the variance of supply shocks, then the decline in the price-output correlation provides support for the views of Kydland and Prescott (1990) and Cooley and Ohanian (1991). However, changes in the variance of the aggregate supply shock imply a negative relationship between the price-output correlation and the variance of output, which is contradicted by the data. More specifically, an increase in the variance of supply shocks always increases the variance of output. Since the post-war declines in the price-output correlation have been accompanied by declines in the variance of output, it must be the case that the ratio of the variance of supply shocks to the variance of demand shocks has increased because of a decline in the variance of demand shocks.[4] This raises the question of why demand shocks have had a lower variance during the postwar period. Importantly, a reduction in the variance of aggregate

[3] Later in the paper we develop a very simple model of the macroeconomy and consider whether other structural changes can, by themselves, explain the observed relationships. We find that they cannot.
[4] A more accurate way of stating this is that the variance of demand shocks must have declined more than any decline in the variance of supply shocks.

demand shocks is consistent with the idea that monetary policy has been stabilizing during the postwar period. It certainly contradicts the idea that discretionary monetary policy has been destabilizing (at least in comparison to the monetary regimes in place during the pre- and inter-war periods).

2. Evidence on the Price-Output Correlation and the Variance of Output

Backus and Kehoe (1992) present data on a large number of macroeconomic variables for ten countries over three time periods. The countries are Australia, Canada, Denmark, Germany, Italy, Japan, Norway, Sweden, UK, and USA. The three time periods are prewar (prior to WW I), interwar, and postwar (after WW II). They present estimates of the standard deviation of the growth rate of output (their Table 1) and the correlation between the growth rates of prices and output (their Table 5). Below these are referred to as the growth rate data. They also apply a Hodrick-Prescott filter to the log-levels of real output and the price level of each country to obtain estimates of the cyclical values of real output and the price level. This allows them to present estimates of the standard deviation of output fluctuations (their Table 2) and the correlation between output and price level fluctuations (their Table 6). Below these are referred to as the filtered data.

Figure 1 presents the growth rate data. The vertical axis measures the standard deviation of the growth rate of output, while the correlation between inflation and output growth is on the horizontal axis. As is shown by the legend, observations for the three different time periods are represented by different symbols and the correlation coefficient for the thirty observations in the figure is 0.67. Hence Figure 1 shows that there is a clear positive relationship between the variability of output growth and the correlation between output growth and inflation. Furthermore, the observations for both the interwar (represented by the black squares) and postwar (represented by the gray circles) periods also clearly show a positive relationship. Only the observations for the prewar period do not show a positive relationship between output variability and the price-output correlation.[5]

The thick vertical dashed line in Figure 1 passes through the observation during the postwar period with the highest correlation between output growth and inflation, while the thick horizontal dashed line passes through the postwar observation with the highest standard deviation of output growth. This divides Figure 1 into four quadrants with all the post war observations in the lower, left-hand quadrant. Notice that there is only one other observation in the lower left-hand quadrant, while there are 13 observations in the upper right-hand quadrant. This indicates that there are 13 observations (5 prewar and 8 interwar) with standard deviations of output growth and correlations between output growth and inflation that are both greater than any of the postwar observations. The increased stability of the 10 countries in the Backus-Kehoe sample during the postwar period is associated with lower correlations between output growth and inflation.

Figure 2 presents the filtered data. The correlation coefficient for the thirty observations in this figure is 0.70, hence Figure 2 also shows a positive relationship between the variability of output and prices. The filtering process produces standard deviations of output fluctuations that are lower than the corresponding standard deviations of output growth for all but six observations. Three of the six exceptions to this are the three observations in the upper right-hand corner of Figure 2—observations on Canada, Germany and the United States during the

[5] This corresponds to the period of the classical gold standard under which the monetary regime was neither a major source of demand shocks nor able to actively offset demand shocks. Thus while differences in policy effectiveness (or ineffectiveness) may explain differences in the price-output correlation and the variance of output across countries in the interwar and postwar period, it cannot do so in the prewar period. As a result, the cross sectional relationship between these two variables is different under the classical gold standard than in the other two periods.

interwar period. When these outliers are omitted, the correlation coefficient for the observations in Figure 2 is 0.63.

The thick vertical dashed line in Figure 2 passes through the observation during the postwar period with the highest correlation between output and price level fluctuations, while the thick horizontal dashed line passes through the postwar observation with the highest standard deviation of output fluctuations. Notice that there are only two non-postwar observations in the lower left-hand quadrant, while there are 11 observations in the upper right-hand quadrant indicating that there are 11 observations (3 prewar and 8 interwar) with standard deviations of output fluctuations and correlations between output and price-level fluctuations that are both greater than any of the postwar observations. Even with the filtered data it appears that the increased stability of the 10 countries in the Backus-Kehoe sample during the postwar period is associated with lower correlations between output and price fluctuations.

The data set just discussed forms a balanced panel. To further examine the extent to which changes in the variability of output are related to changes in the price-output correlation consider the following equation:

$$\sigma_{i,t} = \alpha_{i,t} + \delta\rho_{i,t} + \varepsilon_{i,t} + \eta_t + \mu_i\,; \qquad (1)$$

where $\sigma_{i,t}$ is a measure of the standard deviation of the variability of output growth for country i during time period t; $\rho_{i,t}$ is a measure of the correlation between output growth and inflation for country i during period t; $\varepsilon_{i,t}$ is a mean-zero stochastic disturbance that can vary across both countries and time periods; η_t is a mean-zero stochastic disturbance that varies only across time; μ_i is a mean-zero stochastic disturbance that varies only across countries; $\alpha_{i,t}$ is an intercept term that can vary across country and time; and δ is a slope coefficient that is assumed to be constant across country and time period. If there are no random effects, the variances of η_t and μ_i are equal to zero. If there are no fixed effects $\alpha_{i,t}$ does not vary with i and t. Finally, $t = 1$ refers to the prewar data, $t = 2$ the interwar data, and $t = 3$ the postwar data.

Table 1 presents several estimates of equation (1) using the growth rate data. The first row of Table 1 presents the estimate of δ assuming no fixed effects and no random effects. The second row presents the estimate of δ assuming fixed individual effects, while the third row assumes fixed time effects. The fourth row presents the estimate from the first-differenced data. Note that individual fixed effects are eliminated when the data are differenced. The fifth row employs random time and individual effects. In each case the estimated value of δ is positive and well over twice its estimated standard error.

Table 2 presents estimates for the same set of specifications as those in Table 1 but using the filtered data. In each case presented in Table 2 the estimated value of δ is positive and over three times its estimated standard error. Since Figure 2 suggests a nonlinear relationship between the standard deviation of output fluctuations and price fluctuations, Table 3 presents estimates using the logarithm of the standard deviation of output fluctuations as the dependent variable. Once again, in each case the estimated value of δ is positive and at least three times its estimated standard error.

We are particularly interested in the estimations that employ the first differenced data because we are trying to relate changes in the variance of output to changes in the price-output correlation. The estimates using differenced data presented in Tables 1, 2, and 3 account for country fixed effects (which are differenced out), but not time fixed effects. Now consider the first difference of equation (1):

$$\sigma_{i,t} - \sigma_{i,t-1} = (\alpha_t - \alpha_{t-1}) + \delta(\rho_{i,t} - \rho_{i,t-1}) + \varsigma_{i,t}\,; \tag{2}$$

where ζ_t is a random disturbance that equals $(\varepsilon_{i,t} - \varepsilon_{i,t-1}) + (\eta_t - \eta_{t-1})$ and $t = 2, 3$. Equation (2) allows for time fixed effects because there is a different intercept for each of the two time periods. The change in intercept of equation (2) from one observation to the next captures changes in the variance of output that are the result of differences in the overall economic environment that are not also reflected in the price-output correlation. Changes in the overall economic environment (both across countries and across time periods) that affect both the standard deviation of output as well as the price-output correlation (both across countries and across periods) are captured by the coefficient δ. Estimates of equation (2) are presented in Table 4.

Column (1) of Table 4 shows that part of the increase in the standard deviation of output from the prewar period to the interwar period is unrelated to changes in the price-output correlation. Similarly, the point estimates in column (2) shows that part of the decrease in the standard deviations of output going from the interwar to the postwar period is unrelated to changes in the price-output correlation, but these estimates are not statistically significant from 0. Importantly, column (3) once again shows a positive relationship between the variance of output and the price-output correlation in a model that allows for country and time specific fixed effects.

Hence the estimates presented in Tables 1-4 bear out what is observed in Figures 1 and 2: There is a robust positive relationship between the variance of output and the price–output correlation. It is now appropriate to turn to a simple model in order to show that this relationship must primarily be the result of changes in the variance of the aggregate demand shock across time.

3. A Simple Aggregate Supply and Demand Model

In this section, we present a rudimentary aggregate supply and demand model in order to motivate our discussion of the relationship between the price-output correlation and the variance of output. It should be noted that the same basic implications could be found in a more sophisticated model as well. Our purpose here is to illustrate in the simplest way possible the idea implicit in the notion that the price output correlation can tell us something about the underlying structure of the macroeconomy.[6]

A Lucas (1972) supply curve is presented in equation (3), an aggregate demand curve in equation (4) with the money supply process given by (5):

$$Y_t^S = \gamma(P_t - E_{t-1}P_t) + \varepsilon_S \,, \tag{3}$$

$$Y_t^D = \beta(m_t - P_t) + \varepsilon_D \,, \tag{4}$$

$$m_t = \overline{m} \,. \tag{5}$$

The error terms ε_S and ε_D are i.i.d. with mean 0 and variances σ_S^2 and σ_D^2.[7] In addition, $E[\varepsilon_S, \varepsilon_D] = 0$.[8] The money supply at time *t* is denoted m_t, and by equation (5) this is a constant over time. In a graph with the price level on the vertical axis and the level of output on the horizontal axis the slope of the aggregate demand curve is $-\frac{1}{\beta} \leq 0$, while $\frac{1}{\gamma} \geq 0$ is the slope

---

[6] One way to see that our results are not particularly sensitive to our choice of model is to consider Romer’s (2006, page 533) version of the model employed by Ball (1999) and Svensson (1997). In this model the contemporaneous price-output correlation is positive if there is no policy, but an optimal monetary policy always causes the price-output correlation to be negative (as depicted in Romer’s equation 10.39). See also Carlin and Soskice (2005), especially page 5.

[7] In a more sophisticated model, the aggregate demand shock could be disaggregated into spending shocks, money demand shocks and shocks emanating from the money supply process. In Section 4, we allow for a shock to the money supply process.

[8] If there is an optimizing monetary authority, this could induce a correlation between the aggregate supply and demand shocks. See the discussion in Section 4.

of the aggregate supply curve. We impose rational expectations on the model, where $E_{t-1}P_t$ denotes the expected value of the time *t* price level based on information in period *t-1*.

The solutions for the price level and output are as follows:

$$P_t = \overline{m} + \frac{\varepsilon_D - \varepsilon_S}{\beta + \gamma}, \tag{6}$$

$$Y_t = \frac{\gamma\varepsilon_D + \beta\varepsilon_S}{\beta + \gamma}. \tag{7}$$

From equations (6) and (7), we can derive the following:

$$E(Y_t - E_{t-1}[Y_t])^2 = \sigma_Y^2 = \frac{\gamma^2\sigma_D^2 + \beta^2\sigma_S^2}{(\beta+\gamma)^2} = \frac{\sigma_D^2 + \left(\frac{\beta}{\gamma}\right)^2 \sigma_S^2}{\left(1+\frac{\beta}{\gamma}\right)^2}, \tag{8}$$

$$E(P_t - E_{t-1}[P_t])^2 = \sigma_P^2 = \frac{\sigma_D^2 + \sigma_S^2}{(\beta+\gamma)^2}, \tag{9}$$

$$E\left[(Y_t - E_{t-1}[Y_t])(P_t - E_{t-1}[P_t])\right] = \sigma_{YP} = \frac{\gamma\sigma_D^2 - \beta\sigma_S^2}{(\beta+\gamma)^2}. \tag{10}$$

The variances of output and the price level are given in equations (8) and (9), while the covariance between output and the price level is given in equation (10). Notice that the sign of the covariance depends on the sign of $\frac{\sigma_D^2}{\beta} - \frac{\sigma_S^2}{\gamma}$. If the variance of the aggregate demand shock times the slope of the aggregate demand curve is greater than the variance of the aggregate supply shock times the slope of the aggregate supply curve, then the covariance between unexpected changes in prices and output is positive. Equations (8)-(10) imply that the expression for the price-output correlation coefficient is:

$$\rho = \frac{\sigma_{YP}}{\sigma_Y \sigma_P} = \frac{\dfrac{\sigma_D^2}{\beta} - \dfrac{\sigma_S^2}{\gamma}}{\left(\dfrac{\sigma_D^2}{\beta^2} + \dfrac{\sigma_S^2}{\gamma^2}\right)^{½} \left(\sigma_D^2 + \sigma_S^2\right)^{½}} = \frac{1 - \dfrac{\beta}{\gamma}\dfrac{\sigma_S^2}{\sigma_D^2}}{\left(1 + \dfrac{\beta^2}{\gamma^2}\dfrac{\sigma_S^2}{\sigma_D^2}\right)^{½} \left(1 + \dfrac{\sigma_S^2}{\sigma_D^2}\right)^{½}}. \tag{11}$$

While this model is crude, it captures the basic intuition implicit in the idea that the price-output correlation tells us something fundamental about the structure of the macroeconomy. In particular, ρ will tend to be negative when the variance of the aggregate supply shock is large relative to that of the aggregate demand shock and when the aggregate supply curve is steep relative to the aggregate demand curve. (That is, if β/γ and/or σ_S^2 / σ_D^2 is relatively large, ρ will tend to be negative.).[9]

What does the model imply about the relationship between ρ and σ_Y^2 when the ratio of the variances changes? From (8) we see that $\frac{\partial \sigma_Y^2}{\partial \sigma_D^2} > 0$, while from (11), $\frac{\partial \rho}{\partial \left(\sigma_S^2 / \sigma_D^2 \right)} < 0$. Hence, if σ_D^2 falls, σ_Y^2 and ρ both fall implying a positive relationship between the variance of output and the price-output correlation. Thus, changes in the variance of the aggregate demand shock impart a positive correlation between σ_Y^2 and ρ. The data analysis presented in Section 2, above, shows that for the sample of countries and time periods studied by Backus and Kehoe (1992) such a positive relationship does indeed exist. By contrast, since we also have $\frac{\partial \sigma_Y^2}{\partial \sigma_S^2} > 0$, changes in the variance of the aggregate supply shock impart a negative correlation between σ_Y^2 and ρ. Since Section 2 shows that this relationship is positive, if the negative price-output correlation

[9] We could obtain the same basic conclusions if, instead of having a Lucas supply curve, we had a New Keynesian supply curve. Also, allowing for lagged output to affect current output would not affect our conclusions. See Section 4.1 in Cover and Pecorino (2003).

during the postwar period is the result of an increase in the ratio of the variances (σ_S^2/σ_D^2), it must be the case that the variance of the demand shock has declined (and by more than any decline in the variance of the aggregate supply shock).

An alternative explanation of a negative price-output correlation is that the economy has become more classical during the postwar period. That is, changes in the price level have little or no effect on aggregate supply implying that γ has become relatively small. While a decrease in the value of γ does cause β/γ to increase, it is unlikely that this is the explanation of the decline in the price-output correlation. An increase in the ratio β/γ reduces the price-output correlation, but it does not necessarily reduce the variance of output. From equations (8) and (11) we obtain:

$$\frac{d\sigma_Y^2}{d\left(\beta/\gamma\right)} = \frac{2\sigma_D^2}{\left(1+\dfrac{\beta}{\gamma}\right)^3}\left(\frac{\beta}{\gamma}\frac{\sigma_S^2}{\sigma_D^2}-1\right) \tag{12}$$

$$\frac{d\rho}{d\left(\beta/\gamma\right)} = \frac{-\dfrac{\sigma_S^2}{\sigma_D^2}\left[1+\dfrac{\beta}{\gamma}\right]}{\left(1+\dfrac{\beta^2}{\gamma^2}\dfrac{\sigma_S^2}{\sigma_D^2}\right)^{3/2}\left(1+\dfrac{\sigma_S^2}{\sigma_D^2}\right)^{1/2}} < 0. \tag{13}$$

Although equation (13) implies that an increase in the ratio β/γ reduces the price-output correlation, ρ, equation (12) shows that its effect on the variance of output is ambiguous. But by comparing equation (11) with equation (12) it is clear that an increase in the ratio β/γ will reduce the variance of output if and only if the current value of ρ is positive (i.e., if $1-\frac{\beta}{\gamma}\frac{\sigma_S^2}{\sigma_D^2}>0$). If $\rho < 0$ (i.e., if $1-\frac{\beta}{\gamma}\frac{\sigma_S^2}{\sigma_D^2}<0$), an increase in the ratio β/γ reduces ρ, but raises the variance of output. This is at odds with the data: conditional on $\rho < 0$, the correlation between ρ and σ_Y^2 is

0.79 for the Backus and Kehoe growth rate data and 0.52 for the filtered data. Thus, once the price-output correlation becomes negative, the observed positive relationship between the variance of output and the price-output correlation can only be caused by a reduction in the ratio of the variances, σ_S^2/σ_D^2. It should also be noted from (9) that a reduction in γ raises the variance of the price level and such an increase is not generally observed in the data. (See the discussion below.) Thus, the data are not consistent with the idea that the economy has become more classical during the postwar era. Hence, a steeper aggregate supply curve cannot be the reason for the negative price-output correlations we observe in the data for the postwar period. Moreover, given the relative prominence of labor unions and labor market regulations in the postwar era, it seems unlikely that the 10 economies analyzed by Backus and Kehoe are more classical after WW II than they were prior to WWI.

The discussion above is not meant to imply that a change in σ_D^2 is the *only* factor which varies across countries and across time. However, given the relationships found in the data, our simple model implies that it must be the dominant factor in explaining the positive relationship between the variance of output and the price-output correlation. Changes in σ_S^2 imply a negative relationship between ρ and σ_Y^2 something that is not observed in the data. Changes in the slope ratio, β/γ, do not result in a uniformly positive relationship between ρ and σ_Y^2 over all of the observed values of ρ.

One other aspect of our model worth investigating is the variance of the price level. If aggregate demand shocks are smaller in the postwar era, then from equation (9), the variance of the price level should also be lower in this period. From Table 6 of Backus and Kehoe (1992) we see that the variance of the price level fell in 9 out of 10 countries when comparing the postwar period with the interwar period. However, when comparing the postwar period with the prewar period, the variance of the price level falls in only 6 out of 10 countries. By contrast, the variance of output falls in 9 out of 10 countries when comparing the prewar and postwar periods.[10]

Thus, when comparing the prewar and postwar periods, we observe a sharp move towards the stabilization of output, but only a very weak movement (if any) towards stabilization of prices.[11] The postwar period is marked by discretionary monetary policy. An optimizing monetary authority will attempt to neutralize aggregate demand shocks as this promotes both price and output stability. However, if the monetary authority attempts to neutralize part of the output effects of supply shocks, this will induce greater price level instability.[12] Overall, discretionary monetary policy has a mixed effect on price level stability because central banks apparently do attempt to stabilize output against supply shocks.[13] Thus, it should not be surprising that we see much greater effects on output stability than on price level stability when moving from the prewar gold standard to the postwar period of discretionary monetary policy.

4. The Role of Monetary Policy

If we accept the notion that aggregate demand shocks have been smaller during the postwar period, then it is important to ask why? Given the very different role played by monetary policy during these periods, it seems reasonable to attribute an important role for monetary policy in explaining changes in the variance of aggregate demand shocks across these three periods. During the prewar period the gold standard functioned fairly well. Although there was no discretionary policy to offset demand shocks, the monetary regime nevertheless was generally

[10] Compared with interwar period, the variance of output is lower in all ten countries in the postwar period.

[11] As noted earlier, a decrease in γ causes an unambiguous increase in the variance of the price level. Similarly, from (9), an increase in σ_S^2 also causes an unambiguous increase in variance of the price level.

[12] For example, see equation (21b) in Cover and Pecorino (2003).

[13] See Rotemberg and Woodford (1997, p. 342).

not an independent source of demand shocks.[14] During the interwar period, the failed restoration of the gold standard was a major source of aggregate demand shocks. During this period we generally observe very high values of both the price – output correlation and the variance of output. Finally, although there is at least one major (and extended) policy failure during the postwar period (the Great Inflation), there is nothing approaching the failures of the interwar years.

Models examining how monetary authorities behave typically assume they try to minimize a loss function that includes the squared deviations of output and inflation from their target values. Aggregate supply shocks force the monetary authority to trade-off these two objectives. By contrast, offsetting an aggregate demand shock is consistent with hitting both of these targets. Thus, an optimizing monetary policy will attempt to neutralize aggregate demand shocks. But neutralizing aggregate demand shocks causes declines in both the price-output correlation and the variance of output. That is, the idea that there has been an effective and stabilizing monetary policy during the postwar period is consistent with the observed decline in both the price-output correlation and the variance of output.

To be slightly more formal, consider the following money supply process: $m_t = \overline{m} + \varepsilon_m$, where ε_m is an i.i.d. shock with a variance σ_m^2. In addition to the money supply shock, assume there is an independent aggregate expenditure shock represented by the term ε_E, where ε_E is i.i.d. with a variance σ_E^2. Combining the revised money supply process with the aggregate demand curve in equation (4), yields $Y_t^D = \beta\left(\overline{m} - P_t\right) + \varepsilon_D$, where $\varepsilon_D = \beta\varepsilon_m + \varepsilon_E$,

[14] Perhaps with the exception of the U.S. in the 1890s.

$\sigma_D^2 = \beta^2\sigma_m^2 + 2\beta\sigma_{mE} + \sigma_E^2$, where σ_{mE} is the covariance between the money supply shock and the independent aggregate demand shock.

If $\sigma_{mE} = 0$, then σ_m^2 is a sufficient measure of the quality of monetary policy, where lower values of σ_m^2 imply a superior monetary policy. Suppose, however, that a discretionary monetary policy is potentially stabilizing. A successful discretionary policy would induce a negative covariance between the money supply shock and the expenditure shock (i.e., $\sigma_{mE} < 0$).

First consider the case in which there is no stabilizing discretionary monetary policy. We can model this by assuming that the money supply shock is uncorrelated with the independent aggregate demand shock (as well as with the aggregate supply shock). This implies that the variance of the aggregate demand shock is $\sigma_D^2 = \beta^2\sigma_m^2 + \sigma_E^2$. In this version of the model reductions in the variance of the aggregate demand shock can result from a reduction in the variability of the money supply process. Hence if there is no effective or stabilizing discretionary monetary policy, this model predicts a positive relationship between the variance of output and the variance the money stock. As a description for monetary policy, this is more appropriate for the prewar and interwar periods than in the postwar period. Under the discretionary policies of the postwar period, we should expect $\sigma_{mE} < 0$.[15]

Figure 3 presents a plot of the standard deviation of money growth against the standard deviation of output growth (from Tables 1 and 7 of Backus and Kehoe (1992)). Once again the observations for the three time periods are represented by different symbols. The legend denotes that the correlation coefficient between the thirty observations in Figure 3 is 0.34. If the outlying, prewar observation for Japan is excluded, the correlation coefficient increases to 0.54.

---

[15] Even if monetary policy can only stabilize the price level, but not output, effective policy would require $\sigma_{mE} < 0$.

As a whole the observations in Figure 3 are consistent with this simple model: there is a clear positive relationship between the standard deviation of output growth and that of the growth rate of the money stock. However, as also can be seen from Figure 3, there is no positive correlation between the variabilities of output and money growth for the postwar period. Indeed, as is pointed out by the legend to Figure 3, the correlation coefficient for the postwar observations is -0.11.

This negative correlation between the variabilities of money growth and output growth during the postwar period, however, is consistent with the notion that monetary policy has been stabilizing during the postwar period. An optimal monetary policy offsets independent shocks to aggregate demand causing σ_{mE} to be negative. As the money supply shock becomes more highly correlated with the independent demand shock, the variance of the aggregate demand shock declines, reducing the correlation between the variability of output growth and the variability of money supply growth. Furthermore, if the monetary authority attempts to offset aggregate supply shocks by increasing the money stock whenever there is a negative supply shock, increases in the variability of money growth will be associated with a decrease in the variability of output growth, thereby causing a negative correlation between the two.

For completeness Figure 4 presents the relationship between the variability of money stock fluctuations and output fluctuations using Backus and Kehoe's filtered data. The filtered data tell the same story: there is a positive correlation between the variability of money stock fluctuations and output fluctuations except during the postwar period. Hence the data gathered and tabulated by Backus and Kehoe is consistent with the idea that discretionary monetary policy during postwar era has tended to stabilize output and this change in monetary policy is one cause of the decrease in the variance of output and the main cause of the negative price-output correlation during the postwar period.

Since the postwar sample employed by Backus and Kehoe ends anywhere from 1983 to 1986 depending on the country, it does not include the period of stable growth enjoyed by many economies during the period from 1991 to 2001. Comparing the 1991-1998 period to 1983-1990, Cecchetti, Flores-Lagunes and Krause (2006) find an improved macroeconomic performance in 21 out of the 24 countries which they analyze. They also find that much of this improved performance was due to improved monetary policy. Indeed, they estimate that about 90% of the improved macroeconomic performance of the United States during this period was the result of an improved monetary policy. The argument of this paper implies that if Cecchetti et al. are correct, then the price-output correlation for the period from 1991-1998 should be lower than that for the period 1983-1990. Cover and Hueng (2003) present time-varying estimates of the price-output correlation for the United States. Cover and Hueng (see their Figures 1 and 2) find that the price-output correlation for the United States was largely positive from 1981-1985, close to zero from 1986-1992 and negative from 1993-1999. Hence Cover and Hueng's estimates of the price-output correlation are consistent with Cecchetti et al.'s argument that a good monetary policy was the main source of the improvement in the United States economy during the mid-to-late 1990's.

5. Conclusion

This paper documents a robust positive relationship between the price-output correlation and the variance of output. This relationship is an important stylized fact that a model of the macroeconomy should be able to replicate. We show that this fact can be replicated in a model where aggregate demand shocks affect output, if we allow for a reduction in the variance of aggregate demand shocks over time (relative to any reduction in the variance of aggregate supply shocks). By contrast, if changes in the magnitude of aggregate supply shocks over time have been relatively more important than changes in the magnitude of aggregate demand shocks, there would be a negative relationship between the price-output correlation and the variance of output. Other changes in the structure of the economy, such as a reduced slope of the aggregate supply curve, are not fully consistent with the observed data. Finally, a reduction in the magnitude of aggregate demand shocks is consistent with an improvement in monetary policy during the postwar era.

References.

Backus, David K. and Patrick J. Kehoe, "International Evidence on the Historical Properties of Business Cycles, *American Economic Review* 82, no. 4 (September 1992), pp. 864-888.

Ball, Laurence, 1999, "Efficient Rules for Monetary Policy." *International Finance 2* (April), pp. 63-83.

Carlin, Wendy and David Soskice, 2005, "The 3-Equation New Keynesian Model—A Graphical Exposition." *Contributions to Macroeconomics*: Vol. 5 : Issue 1, Article 13. (Available at: http://www.bepress.com/bejm/contributions/vol5/iss1/art13).

Chatterjee, Satyajit, 1999, "Real business cycles: A legacy of countercyclical policies*?" Business Review - Federal Reserve Bank of Philadelphia*, Jan/Feb 1999, pp. 17-27.

Cecchetti, Stephen G., Alfonso Flores-Lagunes and Stefan Krause, 2006, "Has Monetary Policy Become More Efficient? A Cross-Country Analysis." *The Economic Journal 116* (April), pp 408-433.

Cooley, T. F. and L. H. Ohanian, 1991, "The Cyclical Behavior of Prices," *Journal of Monetary Economics*, vol. 28, August, pp. 25-60

Cover, James Peery and C. James Hueng. "The Correlation Between Shocks to Output and the Price Level." *Southern Economic Journal*, Vol. 70: No. 1, July 2003, pp. 75-92.

Cover, James Peery and Paul Pecorino. "Optimal Monetary Policy and the Correlation between Prices and Output", *Contributions to Macroeconomics*: Vol. 3: No. 1, Article 2, 2003.

Kydland, Finn E. and Edward C. Prescott. "Business Cycles: Real Facts and a Monetary Myth," *Federal Reserve Bank of Minneapolis Quarterly Review*, vol. 14, Spring 1990, pp. 3-18.

Lucas, Robert E., Jr. "Expectations and the Neutrality of Money." *Journal of Economic Theory* (April 1972), pp. 103-24.

Lucas, Robert E., Jr., 1994, "Review of Milton Friedman and Anna J. Schwartz's 'A Monetary History of the United States, 1876-1960'," *Journal of Monetary Economics*, vol. 34, July, pp. 5-16.

Pakko, Michael R. 2000. The Cyclical Relationship between Output and Prices: An Analysis in the Frequency Domain. *Journal of Money, Credit and Banking* 32: 382-399.

Romer, David. *Advanced Macroeonomics, 3rd Edition,* McGraw-Hill/Irwin, New York: 2006.

Rotemberg, Julio J., and Michael Woodford, 1997, "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy," *NBER Macroeconomics Annual 1997* edited by Ben S. Bernanke and Julio J. Rotemberg, MIT Press, Cambridge, MA, pp. 297-346.

Svensson, Lars E. O., "Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets." *European Economic Review 41* (June 1997), pp. 1111-1146.

Wolf, Holger C. 1991. Procyclical Prices: A Demi-Myth? *Federal Reserve Bank of Minneapolis Quarterly Review* 15: 25-28.

Table 1 Estimates with Growth Rate Data

	β (Standard Error)	**First Differenced**	**Fixed Individual Effects**	**Fixed Time Effects**	**Random Individual Effects**	**Random Time Effects**	**$\bar{R}^2$**	**Degrees of Freedom**
(1)	**3.86 (0.80)**	no	no	no	no	no	**0.43**	**28**
(2)	**3.68 (0.85)**	no	**yes**	no	no	no	**0.48**	**19**
(3)	**2.99 (1.12)**	no	no	**yes**	no	no	**0.51**	**26**
(4)	**4.79 (0.89)**	**yes**	---	no	no	no	**0.58**	**19**
(5)	**2.81 (0.98)**	no	no	no	**yes***	**yes***	—	**28**

*Hausman test fails to reject the null hypothesis that the disturbances are uncorrelated with the regressors.

Table 2 Estimates with Filtered Data								
	β (Standard Error)	**First Differenced**	**Fixed Individual Effects**	**Fixed Time Effects**	**Random Individual Effects**	**Random Time Effects**	$\bar{R}^2$	**Degrees of Freedom**
(1)	**3.75 (0.72)**	no	no	no	no	no	**0.47**	**28**
(2)	**3.54 (0.87)**	no	**yes**	no	no	no	**0.43**	**19**
(3)	**3.41 (1.01)**	no	no	**yes**	no	no	**0.52**	**26**
(4)	**4.58 (0.96)**	**yes**	---	no	no	no	**0.54**	**19**
(5)	**3.48 (0.98)**	no	no	no	**yes***	**yes***	—	**28**

*Hausman test fails to reject the null hypothesis that the disturbances are uncorrelated with the regressors.

Table 3 Estimates with Filtered Data—Dependent Variable Log of Standard Deviation of Output Fluctuations

	β (Standard Error)	First Differenced	Fixed Individual Effects	Fixed Time Effects	Random Individual Effects	Random Time Effects	$\bar{R}^2$	Degrees of Freedom
(1)	**0.88 (0.14)**	no	no	no	no	no	**0.54**	**28**
(2)	**0.88 (0.17)**	no	**yes**	no	no	no	**0.56**	**19**
(3)	**0.64 (0.20)**	no	no	**yes**	no	no	**0.60**	**26**
(4)	**1.05 (0.18)**	**yes**	---	no	no	no	**0.63**	**19**
(5)	**0.60 (0.20)**	no	no	no	**yes***	**yes***	**—**	**28**

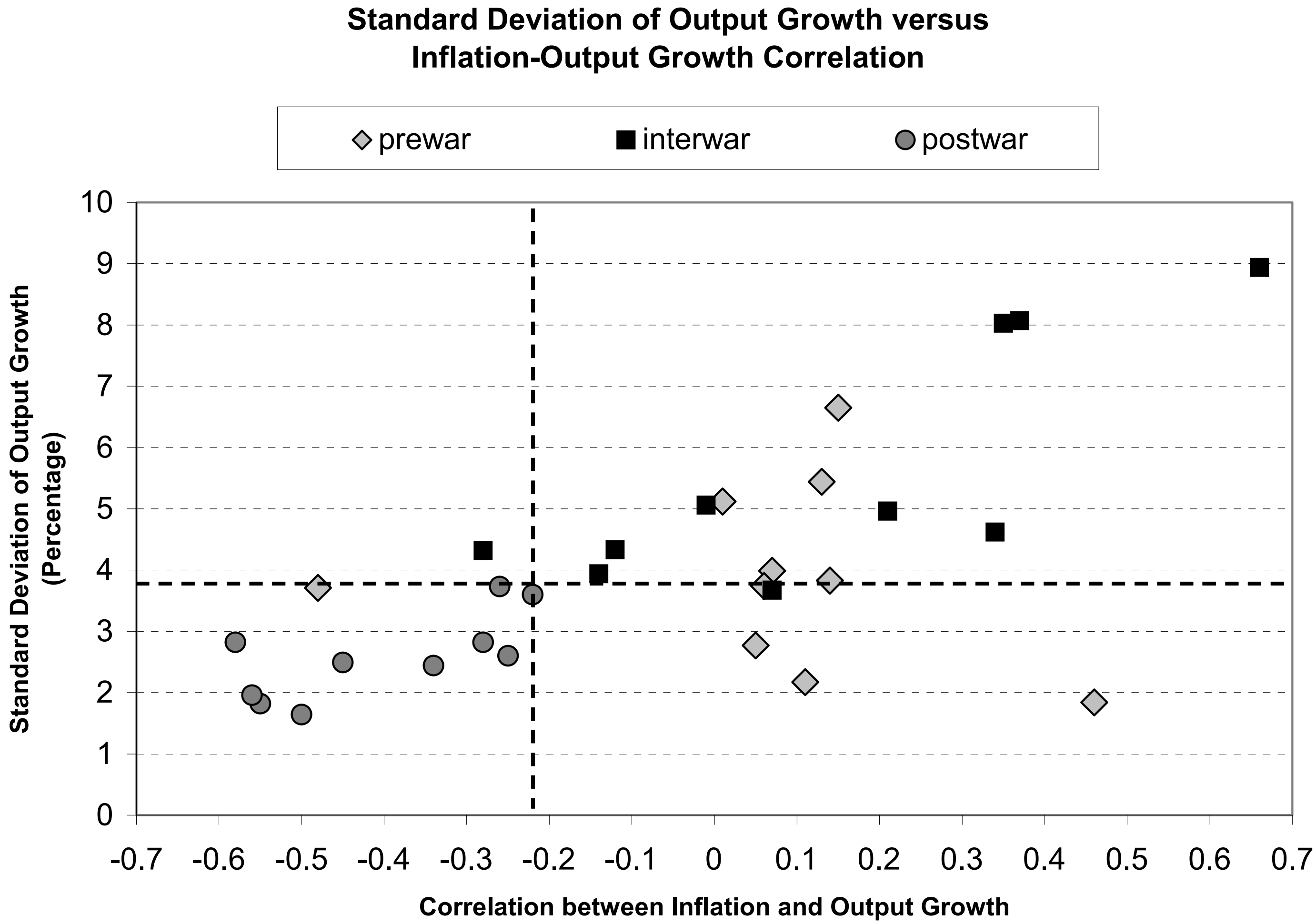
*Hausman test fails to reject the null hypothesis that the disturbances are uncorrelated with the regressors.

Table 4 Estimates with Differenced Data (Equation (2)

column	(1)	(2)	(3)		
	coefficient on				
Data Set	$\alpha_2 - \alpha_1$ (Standard Error)	$\alpha_3 - \alpha_2$ (Standard Error)	$\rho_{i,t} - \rho_{i,t-1}$ (Standard Error)	$\bar{R}^2$	Degrees of Freedom
Growth Rate Data	1.45** (0.53)	-1.45 (0.87)	2.86** (1.29)	0.70	17
Filtered Data	1.64* (0.88)	-1.03 (1.56)	3.25* (1.79)	0.43	17

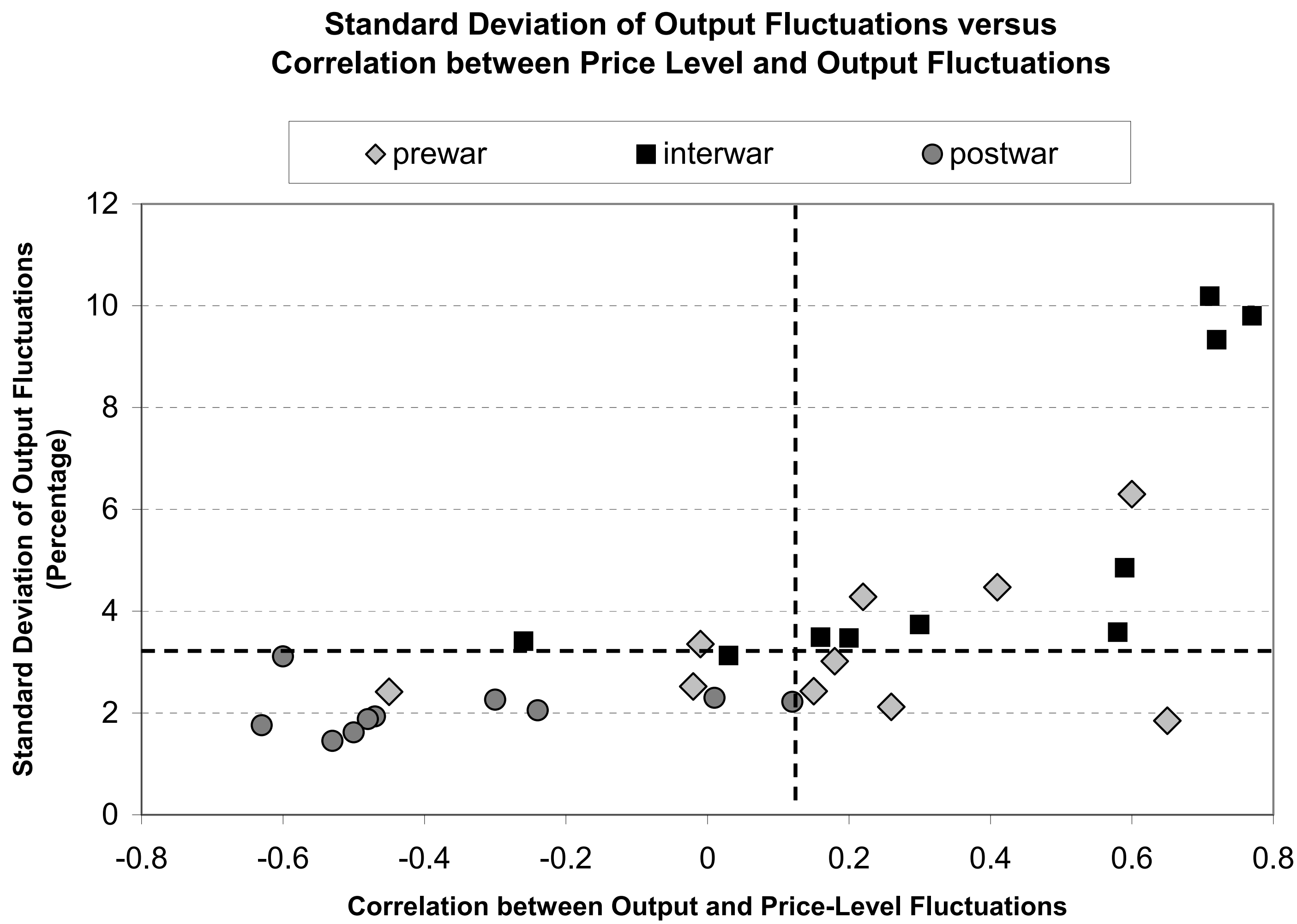
Note: Period *1* contains the prewar data, period *2* the interwar data, and period *3* the postwar data.

Figure 1



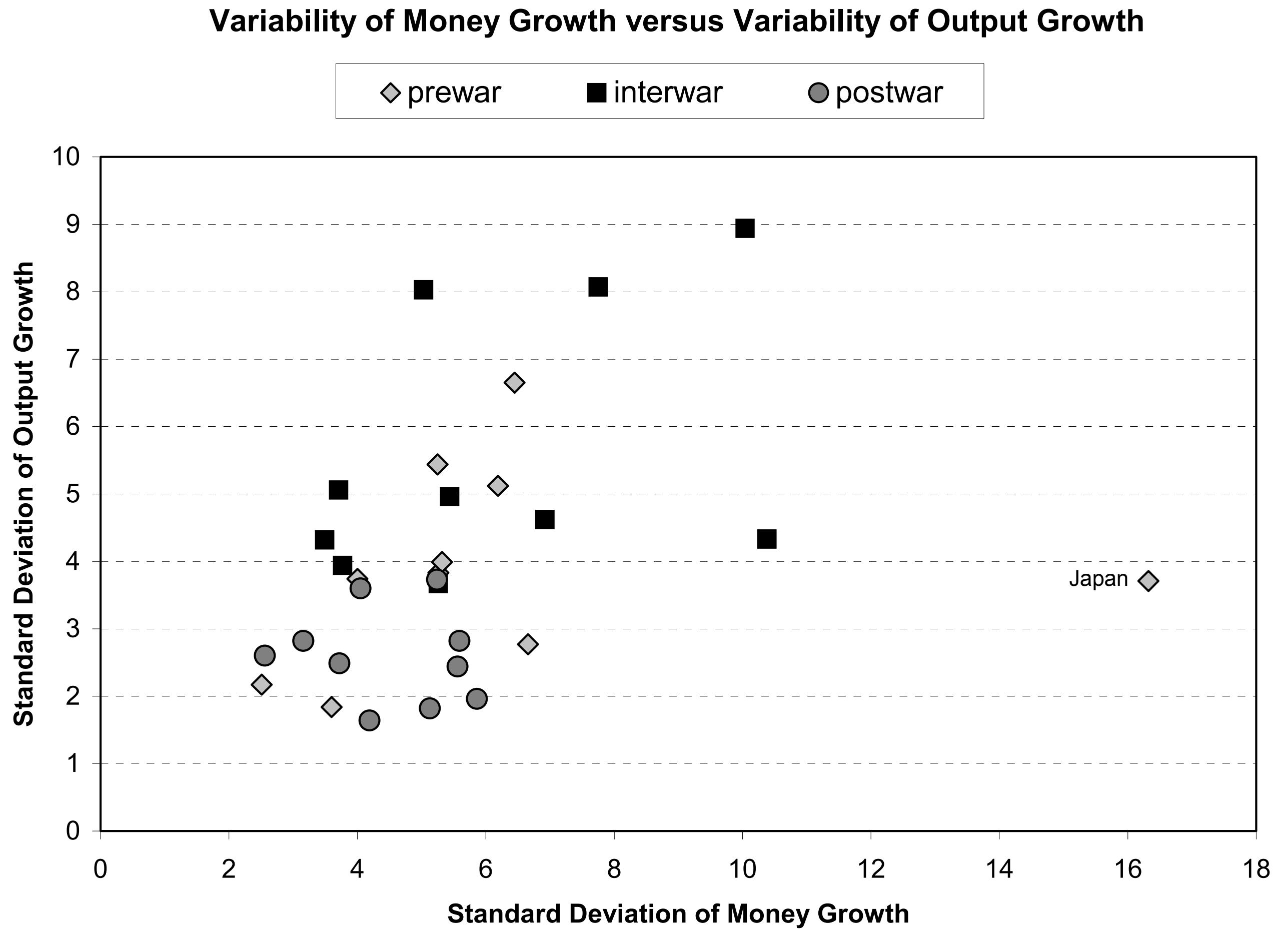
Correlation coefficient = 0.67.

Figure 2



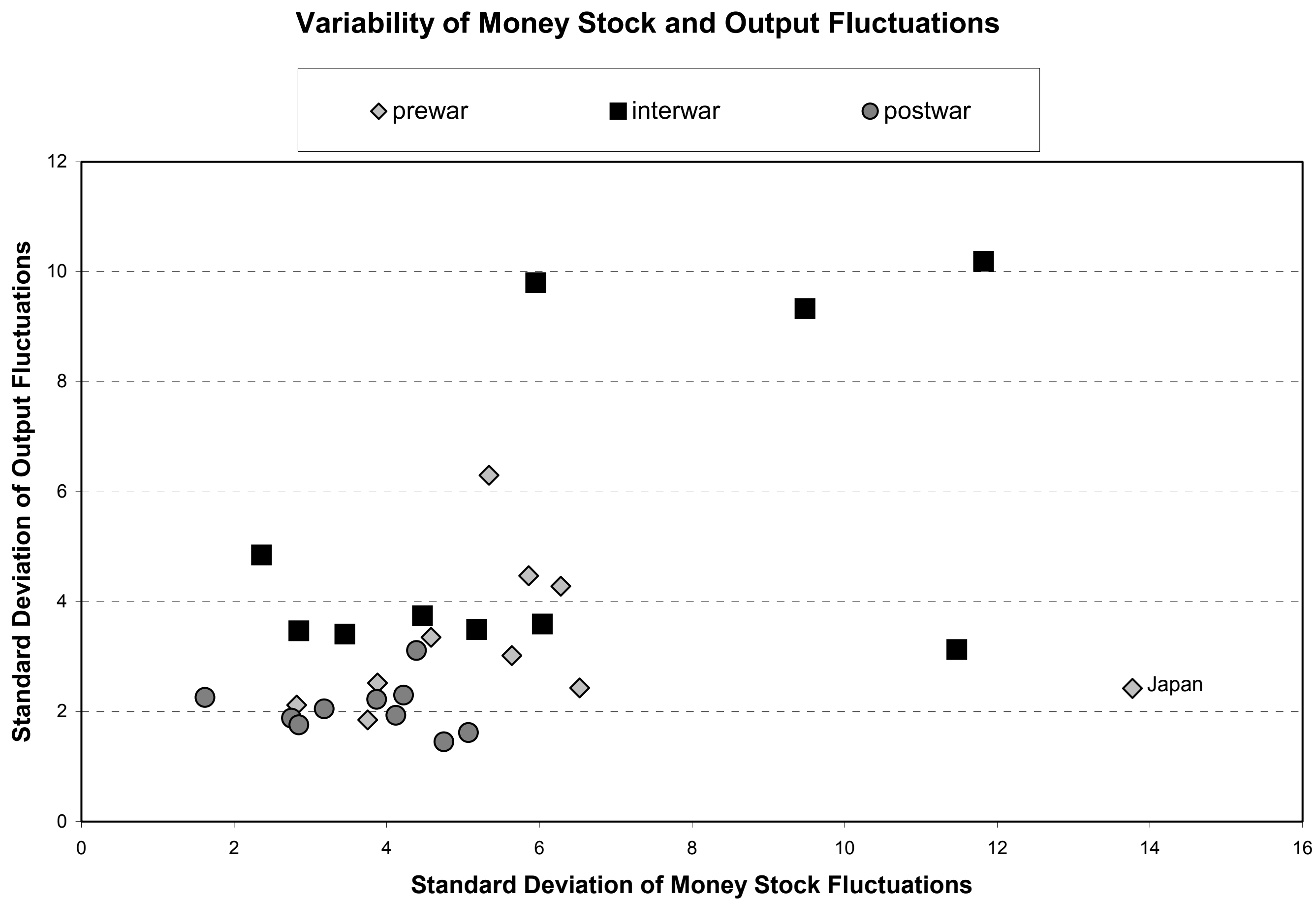
Correlation coefficient = 0.70.
Correlation coefficient excluding outliers = 0.63.

Figure 3



Correlation coefficient all observations: 0.34
Correlation coefficient excluding prewar Japan: 0.54
Correlation coefficient for postwar observations only: -0.11
Correlation coefficient excluding prewar Japan and all postwar observations: 0.54

Figure 4



Correlation coefficient all observations: 0.44
Correlation coefficient excluding prewar Japan: 0.60
Correlation coefficient for postwar observations only: -0.09
Correlation coefficient excluding prewar Japan and all postwar observations: 0.54