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Commentary

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This article begins by asking whether standard endogenous growth models with money, when calibrated to properties of U.S. data, are consistent with the quantitative relationship between inflation and growth documented in the empirical growth literature. V. V. Chari, Larry E. Jones, and Rodolfo E. Manuelli summarize this literature as finding that a 10 percent increase in the rate of inflation implies a 0.2 percent to a 0.7 percent decrease in the growth rate of output. After considering a variety of endogenous growth models with money introduced in a variety of ways, the authors conclude that existing theory does not even come close to accounting for this empirical finding.

Chari, Jones, and Manuelli suggest an explanation for this anomaly. They present indirect evidence that inflation is positively correlated with reserve requirements in actual economies. They then show that the combination of higher inflation and higher reserve requirements is sufficient (within their calibrated theoretical framework) to obtain growth effects of inflation of the magnitude documented in the empirical literature.

THE INFLATION TAX AND GROWTH

How do Chari, Jones, and Manuelli come to these conclusions? In establishing the first point, they consider a variety of ways money can be introduced into a growth model. All of these have the feature that inflation imposes a tax on money holdings, so that an increase in the inflation rate causes households to substitute away from activities involving the use of cash to activities that do not. If the activities involving cash are directly or indi-

rectly related to the accumulation of capital (either human or physical), an increase in the rate of inflation can lower the growth rate of output. The greater the extent that higher inflation induces agents to substitute away from capital accumulation, the larger are the growth effects of inflation.

This theoretical point can be illustrated by considering a set of examples.¹ Suppose, as a first example, that cash is required for a subset of consumption good purchases and that utility depends only on consumption of cash goods and credit goods, but not leisure. In this case, labor is supplied inelastically. An increase in the growth rate of money, and hence the rate of inflation, will cause agents to substitute away from the activity involving the use of cash (consumption of cash goods) to the consumption of credit goods. The presence of this distortion will make agents worse off, but it does not affect their willingness to accumulate capital. Hence, there would be no effect of inflation on growth.

Suppose now, as do Chari, Jones, and Manuelli, that leisure enters the household's utility function. In this case, an increase in the rate of inflation induces agents to substitute into leisure and consumption of the credit good. Hence, the amount of labor employed is lower as a result. In the Lucas model with human capital investment, this has an indirect effect on the amount of capital that agents choose to accumulate. This leads to growth effects that are quantitatively very small, as Chari, Jones, and Manuelli show in Table 1 of their article.

An obvious way to get a direct effect of inflation on capital accumulation is to require that cash be used for purchases of investment goods. The authors, in considering this possibility, introduce the following cash-in-advance constraint:

¹ In the article, four different growth models are considered along with several different motives for holding money. In this discussion, I will limit my attention to the Lucas model and will introduce money by imposing a cash-in-advance constraint.

$$p_t(c_{1t} + \varepsilon(c_{2t} + x_{kt})) - m_{t-1}$$

In this equation, ε is the proportion of credit good consumption and investment in physical capital that must be made with cash. No cash is required for investment in human capital. The authors, after setting $\varepsilon = 0.2$, find that the growth rate falls with an increase in inflation, but the response is too small by a factor of 10 relative to estimates from actual data.

Chari, Jones, and Manuelli could probably have obtained very large growth effects if they had required cash-in-advance for all investment expenditures (set $\varepsilon = 1$).² Given that they are in fact trying to find large growth effects, it may seem surprising that they chose not to consider this case. This seems particularly odd since no justification is given for setting $\varepsilon = 0.2$. Perhaps they were motivated by the standard 20 percent down payment when buying a house.

It is important to understand, however, that the authors are not interested in whether it is theoretically possible to write down models in which inflation has a large effect on growth, but whether models reasonably calibrated to features of the U.S. economy display these effects. They presumably chose not to consider a true "cash-in-advance on everything" example simply because they do not view it as being empirically relevant. Still, it would be more informative, given that no facts are cited to pin down a reasonable range of values for ε , to know how large ε would need to be to obtain the growth effects estimated from the data. Readers could then make up their own minds concerning the empirical relevance of this explanation.

THE ROLE OF RESERVE REQUIREMENTS

The article also examines the possibility that large growth effects might be obtained in an economy in which money is held in the form of required bank reserves in addition to being held by households for purchasing consumption goods. In this model, two types of physical capital are re-

quired to produce output. The first type, k_1 , can be purchased through equity markets and the second, k_2 , must be intermediated through banks. Banks are required to hold a fraction ε of deposits as cash reserves. Hence,

$$R_L = \frac{R_D}{(1 - \varepsilon)}$$

where R_L and R_D are the nominal rate of interest on loans and deposits, respectively. A positive value of ε implies that $R_L > R_D$. In equilibrium, this means that the two types of capital will earn different rates of return. In particular, capital intermediated through banks will earn a higher rate of return than capital financed through equity markets. Any increase in reserve requirements will increase this spread and agents will substitute away from k_2 . This leads to a fall in growth rates.

Because money is effectively required for k_2 purchases, an increase in the inflation rate will lower the growth rate of output for reasons similar to the case where cash is required to purchase a fraction of the investment good. For the calibrated version of this model, in which the required reserve ratio is set equal to .042, Chari, Jones, and Manuelli find that the growth effects of inflation are too small by a factor of 10. This is similar to the result obtained in the previous example. Hence, the introduction of reserve requirements alone does not provide a solution to the puzzle.

CALIBRATION

Because the discipline imposed by calibration is creating the anomaly, it is important to understand how the authors calibrate some of the key parameters underlying their findings. They follow standard calibration practices by specifying a set of measurements (long-run averages) from an actual economy and use the model to back out parameter values so that the steady state of the artificial economy also displays these same properties.³ For example, to calibrate the preference parameter determining how much money

² See Stockman (1981).

³ See Cooley and Prescott (1995) for a detailed description of this methodology.

is held by households, Chari, Jones, and Manuelli rely on the fact that cash held by the public is 2.04 percent of gross national product. For the steady state of the model to display this same property, households must choose to make 43 percent of their purchases with cash.

Second, for the model with intermediated capital, the authors find that the empirical ratio of capital intermediated by banks to gross domestic product (GDP) is 0.39. Given that the total physical capital to GDP ratio is approximately 3 for the U.S. economy, the fraction of capital that is intermediated is relatively tiny. For the model to display this feature, the share of income paid to k_2 must be .054. That is, the k_2 to GDP ratio is used to calibrate the parameter that determines the contribution of intermediated capital in production.

Another important parameter is the reserve requirement, ϵ . Rather than measuring this directly, Chari, Jones, and Manuelli use the fact that 46 percent of their monetary aggregate is held by banks to back out from the model a value of ϵ equal to .042. That is, in this theoretical framework, (1) the total amount of bank deposits is determined by the quantity of intermediated capital and (2) the fraction of deposits held as cash is determined by a reserve requirement. Thus, these two facts together determine the total demand for money by banks.

To resolve the anomaly, the authors consider the possibility that their empirical finding—that 46 percent of the money supply is held by banks—is not invariant to changes in inflation. This possibility implies that inflation leads to more than just households substituting away from activities requiring cash. In particular, Chari, Jones, and Manuelli suppose that the monetary authority increases the reserve requirement at the same time it increases the growth rate of money. Although the authors do not have direct data on reserve requirements, they do find in a cross-section of countries a positive correlation between inflation and the fraction of money held as reserves. Under the main-

tained assumption that any change in the fraction of money held by banks is due to a change in reserve requirements, Chari, Jones, and Manuelli are able to obtain growth effects of inflation of the magnitude observed in the data.

This way of resolving the puzzle amounts to supposing that when a central bank wants to increase seigniorage revenue, it not only increases the growth rate of money, it also increases reserve requirements. However, the correlation they have discovered in the data does not necessarily point to this interpretation. Although it may be the case that the fraction of money held by banks increases with inflation, this does not necessarily imply that reserve requirements are the reason. Chari, Jones, and Manuelli have shown that one of the "facts" used to calibrate the model is not invariant to changes in inflation, but what about the others? It could be that reserve requirements stay constant, but households simply reduce the amount of money they hold. That is, they no longer make 43 percent of their consumption purchases with cash.

The hypothesis of this article is an interesting one and may well survive additional empirical scrutiny. At this point, however, the reader may not be convinced. In the meantime, we can look forward to further interesting work on this topic.

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