Discussion

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Summary

The issue tackled in this paper is an important one: the role of technology shocks for business cycle phenomena. It is especially significant in light of recent findings, which can be summarized as follows. Not only are technology shocks unimportant at business cycle frequencies, but real-business-cycle models poorly explain whatever small role they play. A recent paper by Jordi Galí (1999) best exemplifies the second part of this statement. One provocative result suggests that in response to a positive technology shock, hours worked declines for a long period of time, which seems to be at odds with standard real-business-cycle models. Furthermore, Basu, Fernald, and Kimball (1999) and Shea (1998) obtain similar results using very different methodologies; and Francis and Ramey (2002) show that Galí's result is robust to some alternative identifying assumptions.

In this paper, Christiano, Eichenbaum, and Vigfusson challenge Galí's result using the same methodology, which consists of identifying technology shocks in a vector autoregression (VAR) model as the only disturbances that have a long-term impact on productivity. They show that the response of hours worked to a technology shock is sensitive to the measure of hours used in the VAR. In particular, under the level specification (meaning that hours worked appear in the VAR in levels), hours worked responds positively to a positive technology shock, thereby reversing Galí's result, which obtains under the differenced specification (meaning that the first difference of hours worked appears in the VAR). The authors argue that the evidence broadly favours the level specification, which is consistent with the prediction of standard real-business-cycle models.

Whether hours worked is stationary or not is difficult to assertain given how poorly standard econometrics tests differentiate between persistent and unit-root series. As a first step, the authors use hours worked per capita as opposed to total hours worked, which was used by Galí. It is a step in the right direction, since this is the measure of hours that is built into our standard models. Nevertheless, this series is not clearly stationary, although one would expect hours worked per capita to be stationary in the long term (i.e., in a large sample), given that this series is bounded above and below. Interestingly, the decomposition of this series into hours worked per worker and employment (fraction of the working age population that is working) does not help either, since neither of these series appears to be stationary, whereas hours worked per worker has been declining over the post-war period, and employment has an upward trend. Nevertheless, I will argue below that the distinction between the intensive and the extensive labour margins may be important for other reasons, which is an issue that relates to a common finding in this recent literature.

This finding, consistent with Galí's work, is that technology shocks are unimportant for business cycles. In a similar paper (Christiano, Eichenbaum, and Vigfusson 2003), the authors state that technology shocks in this kind of model account for less than 10 per cent of the cyclical variance of output. Most of my discussion will focus on this result.

1 How Important Are Technology Shocks?

A standard answer to this question can be found in Prescott's (1986a) "Response to a Skeptic," where he suggested that "technology shocks account for more than half the fluctuations [in real output] in the postwar period, with a best point estimate near 75 per cent." The groundwork for these numbers was, of course, his highly cited 1986b paper entitled "Theory Ahead of Business Cycle Measurement."

More recently, Aiyagari (1994, 23) concludes that "Either the contribution of technology shocks must be large (at least 78 per cent), or the predictions concerning the productivity/labor input correlation [which is essentially zero in the data] and the variability of labor input relative to output [about 0.84 in the data] will be incorrect."

The question that arises is: what accounts for the wide discrepancy between these answers and those of the authors? The difference, of course, emanates from the very definition of what constitutes a technology shock.

Recall that Aiyagari was agnostic regarding technology shocks. He derived a model-independent way to measure the importance of technology shocks based on three basic assumptions: (i) the economy operates under perfect competition; (ii) the absence of external economies of scale; and (iii) the absence of measurement error, systematic or not. Under these three assumptions, and given a labour share that is approximately constant at 66 per cent, Aiyagari shows that unless technology shocks are significant, models will be inconsistent with the data in important ways.[1]

The technology shocks that Prescott and Aiyagari referred to were broadly defined as shocks that directly affect the aggregate production technology frontier, a definition that differs widely from the interpretation given to technology shocks in the papers of Galí or Christiano, Eichenbaum, and Vigfusson.

Consider the following reduced-form model, which corresponds to Galí's model and to the differenced specification in the authors' paper:

$$\begin{bmatrix} \Delta f_t \\ \Delta n_t \end{bmatrix} = \begin{bmatrix} C^{11}(L) & C^{12}(L) \\ C^{21}(L) & C^{12}(L) \end{bmatrix} \begin{bmatrix} \in_t^z \\ \in_t^o \end{bmatrix},$$

where f_t represents average labour productivity and n_t is a measure of hours worked. In this simple model, the vector, $[\Delta f_t, \Delta n_t]'$, is expressed as a distributed lag of two types of shocks, labelled $\in_t^z$ and $\in_t^o$.

One of the main insights on which Galí builds is that only *permanent* technology shocks should have a permanent effect on productivity. This implies that the unit-root lag associated with shocks that are not permanent technology shocks, $\in_t^o$, should be set equal to zero, that is, $C^{12}(1) = 0$. Before discussing the implications of this assumption, it should be mentioned that for identification purposes alone, there is nothing special about zero; any value of $C^{12}(1)$ would do just as well. In particular, as Sarte (1997) pointed out, permanent changes in income tax rates in real-business-cycle models have a permanent impact on measured productivity. Using this insight as an identifying restriction in the above VAR (i.e., employing the differenced specification), Sarte shows that the implied response to a positive technology shock has the qualitative features of the level specification of Christiano, Eichenbaum, and Vigfusson (see Sarte's Figure 3). This is another example of the well-known fact that any result obtained through a VAR exercise is, to a large extent, dependent on the assumption(s) necessary to identify the parameters of the model.

1. Aiyagari recognizes that moving away from perfect competition or the presence of economies of scale would lower the contribution of technology shocks.

Nevertheless, if one is willing to believe Galí's identification assumption, then one can identify $\in_t^z$ as permanent technology shocks. Sure enough, as emphasized by Christiano, Eichenbaum, and Vigfusson, the long-run response to such shocks is in line with the neo-classical growth model, which was designed to explain such phenomena. The short-run response to such shocks should not be viewed as a reason to dismiss or to reinforce how we think of standard real-business-cycle models, nor would the effect of such shocks on the economy be particularly helpful in explaining how the economy behaves at business cycle frequencies. These are permanent shocks, which have the impact that we would expect in the long run. Although it would be highly desirable, as I will argue, to have models capable of replicating the empirical response (whichever one it is) to these shocks at business cycle frequencies, these shocks should not be expected to be the driving force behind business cycle phenomena. The economy does, however, respond to non-permanent technology shocks—identified as $\in_t^o$ in the model—in ways that are broadly consistent with standard real-business-cycle models.

But what are these other shocks? Arguably, some of them could correspond to monetary or fiscal policy shocks. Nevertheless, an interesting interpretation, which these reduced-form models cannot preclude, is that a significant portion of these shocks corresponds to persistent, but ultimately temporary, technology shocks. With this interpretation, the implicit results of this paper no longer contradict Aiyagari's results, which were based on a much broader view of what represents technology shocks. Ultimately, these shocks may or may not have anything to do with technology per se, but they do have the property that they shift the production technology frontier. In fact, one could argue that the problem is in the language used, not in the theory itself. And if we want to be more precise about what constitutes technology shocks, then we should be able to identify them with particular events. Otherwise, a more agnostic view of these "technology shocks" is perhaps more appropriate.

Evidently, even this interpretation leaves important questions unanswered, since the economy appears to respond differently to permanent technology shocks than it does to persistent (yet temporary) ones.[2] The next section proposes some avenues that I believe could shed light on this issue.

2. Francis and Ramey (2001) show that a real-business-cycle model with habit persistence and investment adjustment costs is consistent with Galí's results. They do not, however, consider the impact of temporary technology shocks.

2 Interesting Avenues

The above discussion leads me to conclude that we need to think about how the impact of persistent but ultimately temporary technology shocks differs from that of permanent technology shocks. In other words, we must think about models in which the propagation of permanent and transitory shocks to technology differs, and does so in ways that are consistent with the data. This is presumably the conclusion reached by two of the authors of this paper, since they are currently in the process of studying the impact of many different shocks, including temporary and permanent technology shocks, in Altig, Christiano, Eichenbaum, and Linde (2002).

Another potentially important direction is to further explore the implications of modelling both the extensive and the intensive labour margins. As documented by Greenwood, Seshadri, and Vandenbroucke (2002), long-run changes in productivity are important to explain changes in the extensive margin, whereas standard real-business-cycle models with temporary technology shocks mainly concern the intensive margin.[3] Andolfatto's (1996) results suggest that a standard real-business-cycle model modified to incorporate labour market search along the lines of Pissarides (2000) is able to explain the fact that about two-thirds of the variation in total hours worked come from the intensive margin and one-third from the extensive margin. Of course, Andolfatto considers only temporary technology shocks. Nevertheless, the transmission of permanent and transitory shocks may be very different in such environments. For instance, one would think that the intensive margin would respond more than the extensive margin following a transitory shock, whereas the opposite might obtain for permanent shocks—at least with a lag.

Finally, vintage capital models, where technology is embodied in capital, may also be of interest. In these models, the reallocation of resources, including employment, following a permanent shock may be very different from that following a temporary shock. For example, one of the features of Campbell's (1998) model is that employment can actually fall following a permanent improvement in technology. Another form of technology shocks that Greenwood, Hercowitz, and Krusell (1998) consider is investment-specific technological change. Their findings suggest that approximately 30 per cent of output fluctuations can be attributed to this form of technological change.

3. There are exceptions, of course, e.g., Hansen (1985) and Rogerson (1988).

Conclusions

This paper makes an important point regarding the empirical response of hours to permanent technology shocks. Although the arguments are not entirely convincing, they certainly go a long way in casting doubts on the results of Galí (1999). More importantly, this type of work makes us think hard about the nature of technology shocks. On all accounts, I believe that more work will be necessary for an agreement to be reached.

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