

DO TECHNOLOGY SHOCKS LEAD TO A FALL IN TOTAL HOURS WORKED?

Harald Uhlig

Humboldt University Berlin,
University of Tilburg, and CEPR

Abstract

This paper contributes to the debate initiated by Galí in 1999. I provide a theory with capital income taxation, labor hoarding as well as long-run shifts in the social attitudes to the workplace—modelled as “leisure at the workplace”—to argue that there are other shocks that may influence labor productivity in the long run. I introduce “medium-run identification” and show it to be superior to long-run identification or standard short-run identification, when applied to artificial data. With U.S. data and medium-run identification, I find the robust result that technology shocks lead to a hump-shaped response of total hours worked, which is mildly positive following a near-zero initial response. (JEL: E32, E24, C32, C15)

1. Introduction

What drives business cycles? We still do not know. The search is on for a quantitative theoretical model, which is able to match a number of key empirical features of the data while driven by a small set of shocks only. The alternative is that the explanation requires an intricate interplay or a variety of stochastic disturbances, as in Christiano, Eichenbaum, and Evans (2001) or Smets and Wouters (2003). Some of the key business cycle facts are listed in Table 1. In particular, the positive co-movement between labor productivity and output, has invalidated simple, traditional explanations of the business cycle.

The real business cycle literature has therefore focussed on technology shocks as the key driving force, see for example, Cooley and Prescott (1995) or King and Rebelo (1999) and the classic references therein. But that line of explanation has come under increasing attack in the literature, see for example, Shea (1998) or Basu, Fernald, and Kimball (1999). Using long-run identification, Galí (1999) and Francis and Ramey (2001, 2003) in particular have argued

Acknowledgments: I am grateful to Neville Francis and Valerie Ramey for providing me their data. I am grateful to comments received at the EEA meeting in Stockholm 2003, and at seminar audiences at the ECB, CEMFI, Alicante and Carlos III. All remaining errors are my own.

E-mail address: uhlig@wiwi.hu-berlin.de

TABLE 1. Some key business cycle facts

	Real output		Hours		Labor prod.		Wages	
	HP	Δ	HP	Δ	HP	Δ	HP	Δ
Real output	1	1						
Hours	0.86	0.70	1	1				
Labor prod.	0.54	0.68	0.04	-0.05	1,	1		
Real wages	0.14	0.19	-0.10	-0.23	0.50	0.51	1	1

Notes: The data is in logs of quarterly postwar U.S. data, focussing on production in the private sector, and taken from Francis and Ramey (2001). HP refers to the Hodrick-Prescott Filter with $\lambda = 1,600$, whereas Δ indicates taking the first difference of the series.

that technology shocks can hardly be the key source of business cycle fluctuations, since they are estimated to lead to falling rather than rising labor input. Their findings have in turn been contested by, for example, Fisher (2002), Christiano, Eichenbaum, and Evans (2003), Michelacci and Lopez-Salido (2003), and others.

This paper contributes to this debate by re-examining the theoretical foundations for the long-run identification of technology shocks. I argue that labor productivity can be moved in the long run also by changes in dividend taxation as well as changes in the social attitude towards the workplace, and not just technological improvements. I introduce a very simple and novel model of labor hoarding as “leisure at the workplace” in business cycle theories. Empirically, and as an alternative to long-run identification, I introduce and propose medium-run identification, try it out on artificial data generated by some theories and then apply it to the data. Following Christiano, Eichenbaum, and Evans (2003), I do not first-difference hours. In contrast to long-run identification, medium-run identification leads to the fairly robust results, that technology shocks lead to a humpshaped response of total hours worked, which is mildly positive following a near-zero initial response.

2. Long-Run Productivity: Some Theory

The evidence in Galí (1999) and Francis and Ramey (2001, 2003), that technology shocks lead to a fall in total hours worked comes from estimated VARs, in which technology shocks are identified by the restriction, that they are the only source of long-run stochastic movements in labor productivity. While this can be justified by simple business cycle theories, in which technology has a unit root and technological progress is exogenous, this is difficult to justify more generally. Most obviously, in endogenous growth models, any shock may end up shifting labor productivity in the long run. Here, I shall pursue models with exogenous technological progress, but two other potential sources of changes in long-run labor productivity: dividend taxation as well as long-run shifts in the

social attitude towards the workplace. Both will lead to short-run movements in opposite directions for labor and labor productivity, which may thus partially explain Galí's (1999) findings. I shall also assume technology to be trend-stationary: technology shocks will not have any long-run impact on any variable, including labor productivity. There only will be a relationship among the various deterministic trends.

Ultimately, it is desirable to provide a model which both accounts for the variety of empirical findings as well as provide a successful explanation of business cycles. But this is an ambitious goal which has to await future work. The purpose of this section is much more modest. It is to build a workhorse model containing some of the features that may be essential to understanding productivity movements, and with which one can examine the success of econometrically identifying technology shocks, when applied to simulated data. Importantly, our model will have the feature that neither short-run, medium-run, nor long-run identification will exactly identify the technology shock: the most one may hope for is to come close.

For dividend taxation, consider Figure 1, which shows U.S. tax rates on corporate dividends, obtained from Ellen McGrattan's web site. The eyeball impression, that this series is very persistent or even nonstationary can be confirmed by fitting low-order AR processes to this series.

For social attitudes toward the workplace, I refer to anecdotal evidence that people increasingly regard the workplace as a place for social interaction and a substitute for leisure activities at home. The office has become a place for finding marriage partners, for surfing the Internet, even for enjoying recreational facilities, receiving massages or celebrating a variety of special events. For a number of activities, the boundaries between work and leisure have become increasingly blurred. Is a "power lunch" with another manager lunch or work?

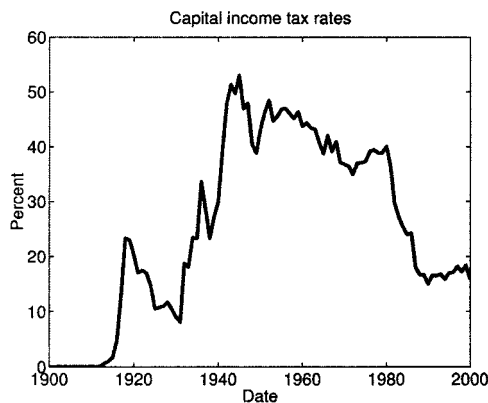


FIGURE 1. United States dividend tax rate. Source: McGrattan.

What about business trips to destinations, that others might visit as tourists? Accordingly, measured labor input has shifted in permanent ways vis-à-vis actual labor input, resulting in permanent changes in measured labor productivity.

This effect is related to labor hoarding, which has often been proposed as an explanation for why labor productivity may move procyclically, even if production is demand-driven. To exclude the possibility of measuring technology shocks simply by their short-run impact on labor productivity, I will therefore allow for labor hoarding in my theory.

I propose to model labor hoarding as well as the social attitude towards the workplace in a very simple (and possibly overly simplistic) way as follows. I assume hours at work to generally exceed actual work hours, and assume that agents regard this extra time spent at work as “leisure at the workplace” and a perfect substitute for leisure outside of work. The workplace leisure activities can be adjusted on short notice to allow for the necessity to work more, without changing measured work hours much.

More precisely, I shall assume that contract hours (and thus measured hours) $n_{c,t}$ are the sum of actual work hours n_t and workplace leisure $l_{n,t}$,

$$n_{c,t} = n_t + l_{n,t}$$

and that wages per contract hour $w_{c,t}$ are calculated precisely such that they correspond to the marginal product of labor w_t paid to actual hours worked,

$$w_{c,t}n_{c,t} = w_t n_t$$

Agents are assumed to be endowed with one unit of time, so total leisure is equal to $l_t = 1 - n_t = l_{n,t} + l_{h,t}$, where $l_{h,t}$ is home leisure. I assume that agents care only about total leisure l_t , and not the individual components.

With these assumptions, there is no economic force pinning down contract hours. Contract hours and thus contract labor productivity are simply mismeasurements of true hours worked and true labor productivity. I assume an exogenous process for contract hours by assuming the difference between contract hours and some fixed multiple of actual hours to be closing at a certain speed, subject to shocks, which reflect shifts in the social attitude towards the workplace,

$$n_{c,t} = \rho n_{c,t-1} + (1 - \rho)\Phi n_t + \eta_t$$

where $\Phi \geq 1$ and η_t is an AR(1) process, $\eta_t = \psi_\eta \eta_{t-1} + \varepsilon_{\eta,t}$, $\varepsilon_{\eta,t} \sim \mathcal{N}(0, \sigma_\eta^2)$. To model short-run shifts or long-run shifts, I adjust the value of ρ or the persistence of η_t .

Clearly, more economic theory to determine $n_{c,t}$ would be desirable, in order to tie down the degrees of freedom here, or to tie it to more fundamental

preference and contract parameters. An alternative route to microfoundation may be the nonlinear aggregation of labor supply choices in heterogeneous-agent economies; see Maliar and Maliar (2003), Equation (A.21). On the other hand, exogenous assumptions about how to for example, split the surplus in wage bargaining and thus the persistence of nominal wages have been used by Hall (2003) and others: my assumptions have a somewhat similar flavor. Furthermore, this formulation is simpler to use and offers more possibilities for persistence than, for example, Burnside, Eichenbaum, and Rebelo (1993).

To complete this model, I consider a standard real business cycle model with labor hoarding as described previously, with stochastic shocks to the time endowment (alternatively interpretable as preference shocks) and with an exogenous process for dividend taxes. I assume technology to be persistent, but not with a unit root, and assume dividend taxes to be more persistent than technology. Dividend tax shocks are announced one period in advance. Given dividend taxes and given constant government spending, wage taxes are calculated endogenously to make the government balance its budget period by period.

Formally, preferences are assumed to be

$$E \left[\sum_{t=0}^{\infty} \beta^t \frac{(c_t^{1-\alpha}(\mu_t - n_t)^\alpha)^{1-\eta} - 1}{1 - \eta} \right]$$

and subject to exogenous preference shocks, $\mu_t = (1 - \psi_\mu)\bar{\mu} + \psi_\mu\mu_{t-1} + \varepsilon_{\mu,t}$, $\varepsilon_{\mu,t} \sim \mathcal{N}(0, \sigma_\mu^2)$. Production is Cobb–Douglas,

$$c_t + x_t = y_t = \gamma_t k_{t-1}^\theta n_t^{1-\theta}$$

with $z_t = \log(\gamma_t)$ exogenous as $z_t = \psi_z z_{t-1} + \varepsilon_{z,t}$, $\varepsilon_{z,t} \sim \mathcal{N}(0, \sigma_z^2)$. Wages w_t are the marginal product of labor, while dividends d_t are the marginal product of capital. Wage taxes are given by

$$\tau_t^n w_t n_t = \bar{g} - \tau_t^k (d_t - \delta) k_{t-1}$$

where dividend taxes τ_t^k exogenously follow $\tau_t^k = (1 - \psi_{\tau_k})\bar{\tau}_k + \psi_{\tau_k}\tau_{t-1}^k + \varepsilon_{\tau,t}$, $\varepsilon_{\tau,t} \sim \mathcal{N}(0, \sigma_{\tau_k}^2)$. Capital is accumulated linearly,

$$k_t = (1 - \delta)k_{t-1} + x_t$$

I solve for the competitive equilibrium.

As parameters, where t counts years, I choose $\alpha = 2/3$, $\theta = 1/3$, $\delta = 0.1$, $\psi_z = 0.95^4 = 0.81$, $\sigma_z = 0.7 * 2 = 1.4$, $\bar{g}/\bar{y} = 22\%$, $\bar{\tau}_k = 25\%$ and thus $\bar{\tau}_n = 28\%$, see Cooley and Prescott (1995) or use NIPA averages. Further, I experiment with $\psi_{\tau_k} = 1$, $\sigma_{\tau_k} \in \{0; 3.3\%\}$, $\Phi = 1.2$, $\rho \in \{0; 0.5; 0.8\}$, $\psi_\eta \in \{0; 1\}$, $\sigma_\eta \in \{2\%; 0.1\%; 0\}$, $\psi_\mu = 0.8$, $\sigma_\mu \in \{0\%; 3\%\}$ to allow for a variety of

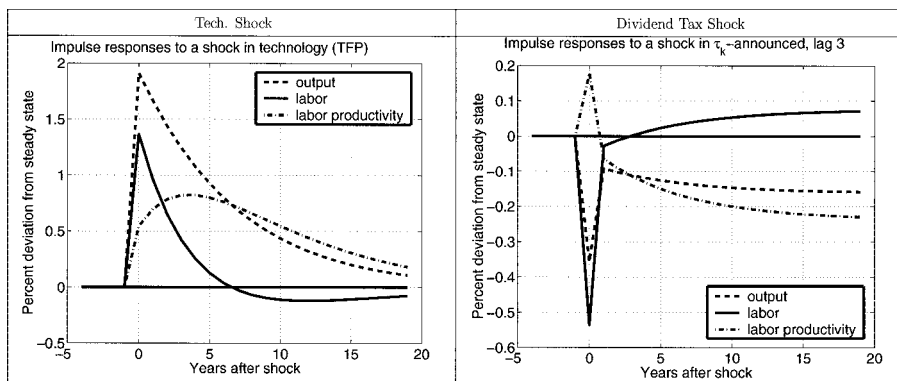


FIGURE 2. Impulse responses, with labor hoarding “turned off”.

artificial economies on which to try out econometric identification of technology shocks.

The impulse response to a technology shock and a dividend tax shock, when labor hoarding is turned off, are shown in Figure 2. Note that the dividend tax shock is a shock with permanent effect of labor productivity. On impact, labor moves down, and productivity up, since the disincentive to save makes agents reallocate to current consumption of goods and leisure, inducing labor to decline. Since capital is predetermined, productivity moves up. Eventually, productivity declines (and labor rises), as capital is adjusted downwards relative to labor. While this shock has permanent effects on labor productivity, and while it leads to short-run opposite movements in labor and labor productivity, it cannot by itself explain the empirical findings of Galí, since the productivity impulse response changes sign.

Conversely, with persistent preference disturbances and contract disturbances, $\psi_\mu = 0.8$, $\sigma_\mu = 3\%$, $\rho = 0.8$, $\psi_\eta = 1$, $\sigma_\eta = 0.1\%$, but dividend tax shocks turned off, Figure 3 shows, how labor hoarding allows this model to generate procyclical measured labor productivity movements in response to preference shocks.

3. Medium-Run Identification

The workhorse model of the preceding section can now be used to simulate artificial data and run experiments of econometrically identifying technology shocks. To provide some structure, consider a first-order identified VAR in, say, labor productivity and total hours worked,

$$x(t) = Bx(t-1) + A\varepsilon_t, \quad E[\varepsilon_t \varepsilon_t'] = I$$

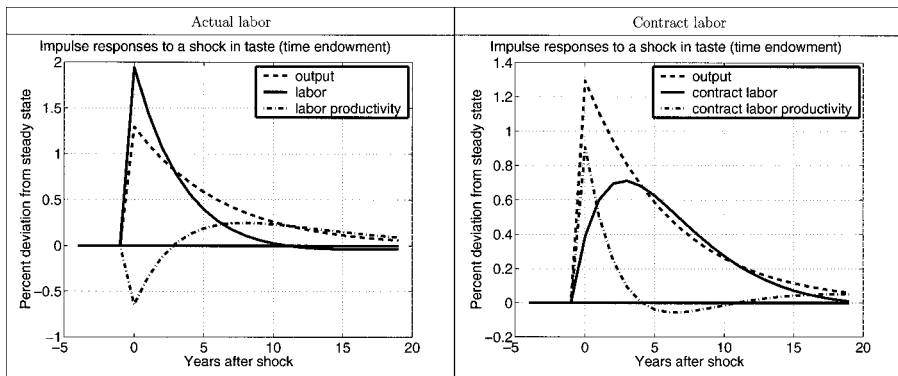


FIGURE 3. Impulse responses to preference shocks: comparing actual labor to contract labor.

fitted to the data. The k -step ahead forecast revision is given by

$$\varepsilon_{t,k} = E_t[x(t+k)] - E_{t-1}[x(t+k)] = B^k A \varepsilon_t$$

and has variance-covariance matrix $\Sigma_k = B^k A A' (B')^k$. It can be decomposed into the contributions of each shock $j = 1, \dots, k$ per

$$\Sigma_k = \sum_{j=1}^k \Sigma_{k,j}, \quad \text{where } \Sigma_{k,j} = B^k A E_{jj} A' (B')^k$$

and where E_{jj} is the zero matrix, with only the j -th element on the diagonal replaced by 1. With this, one can calculate $\phi_{i,j,k} = (\Sigma_{k,j})_{ii} / (\Sigma_k)_{ii}$ as the fraction of the k -step ahead forecast revision variance for variable i , explained by shock j .

To identify technology shocks, and if one does not wish to estimate some complete structural model like the one of the preceding section, it is attractive to proceed by ordering labor productivity first, do a Cholesky decomposition of some $\Sigma(k) = C_k C'_k$, C_k lower triangular, and find some A satisfying $C_k = B^k A$ as well as $\Sigma(0) = A A'$ (the latter is no restriction, if B is invertible). The first shock (one standard-deviation in size) then has the one-step ahead prediction error given by the first column of A and explains all of the k -step ahead forecast revision of labor productivity. Standard short-run identification uses $k = 0$, noting that the one-step ahead prediction error is the 0-step ahead prediction revision in the terminology here. The long-run identification of Blanchard and Quah (1989) and Galí (1999) uses $k = \infty$. In this paper, I propose to consider and use medium-run identification, decomposing Σ_k for some suitable $0 < k < \infty$. As an extension, one may wish to focus on sums of Σ_k , requiring principal-components analysis, see Uhlig (2003).

For two parameter specifications of the theory, Figure 4 plots $\phi_{i,j,k}$ and

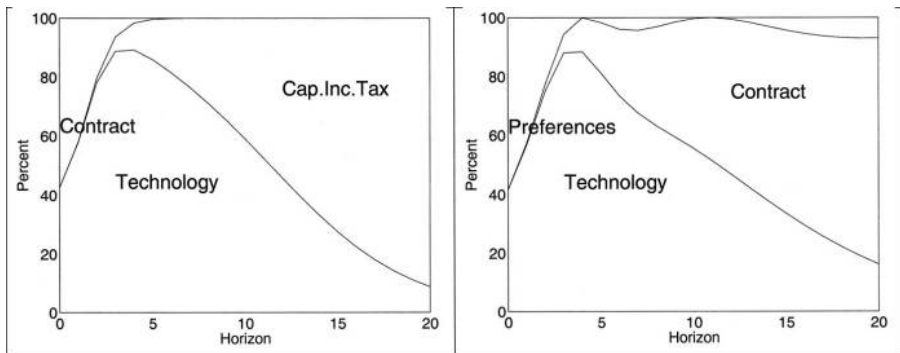


FIGURE 4. Decomposition of k -step ahead forecast error revision variances. Left: $\sigma_{\tau_k} = 3.3\%$, $\rho = 0.5$, $\psi_\eta = 0$, $\sigma_\eta = 2\%$, no preference shocks. Right: $\psi_\mu = 0.8$, $\sigma_\mu = 3\%$, $\rho = 0.8$, $\psi_\eta = 1$, $\sigma_\eta = 0.1\%$, dividend tax shocks turned off.

shows that technology shocks contribute most to the variance of productivity forecast revision variances at intermediate horizons of about three to ten years out. Further, there is no horizon, at which technology shocks alone explain labor productivity. Thus, neither short-run, medium-run, nor long-run identification will exactly identify the technology shock: the most one may hope for is to come close. Figure 5 applies these to artificial data from the specification with persistent preference and contract shocks. Medium-run identification works better than the other two. In particular, the true technology impulse response of

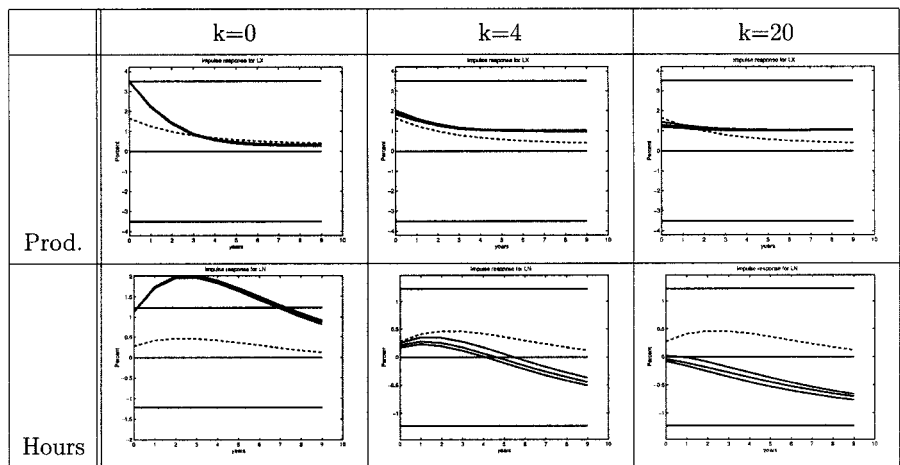


FIGURE 5. Impulse responses: Comparing theory to estimates based on identified VARs in labor productivity and labor. Fitted to a sample of 10,000 observations generated from the model specification with persistent preference and contract shocks. Σ_∞ has been approximated by Σ_{20} . Shown are the median response as well as the 16% and the 86% quantiles.

labor is best identified with the medium-run identification scheme. Similar results, not shown, obtain for other parameter specifications.

4. Application to the Data

With these encouraging results, I apply medium-run identification to U.S. data. I used a Bayesian VAR, and fitted it to annual data provided by Francis and Ramey (2003) for private sector labor productivity and total hours worked (divided by the population above age 16) as well as dividend tax rates taken from McGrattan’s web site. I first take a postwar sample in Figure 6 and then use a sample from 1889 to 2002 in Figure 7. I use $k = 20$ to capture long-run identification similar to Blanchard and Quah (1989), thus avoiding imposing a unit root on the parameter space, and compare my proposed medium-run identification of the four-year-ahead prediction error revision covariance matrix to this long-run identification as well as the standard Cholesky decomposition of $\Sigma(0)$. I have used level labor in both cases, following the suggestion of Christiano, Eichenbaum, and Vigfusson (2003).

I observe that medium-run identification provides the most robust results. Long-run identification would lead one to conclude that labor rises, when using postwar data—this is the point in Christiano, Eichenbaum, and Vigfusson (2003)—but one would conclude that labor falls in the longer sample. By contrast, medium-run identification delivers a hump-shaped response, which is

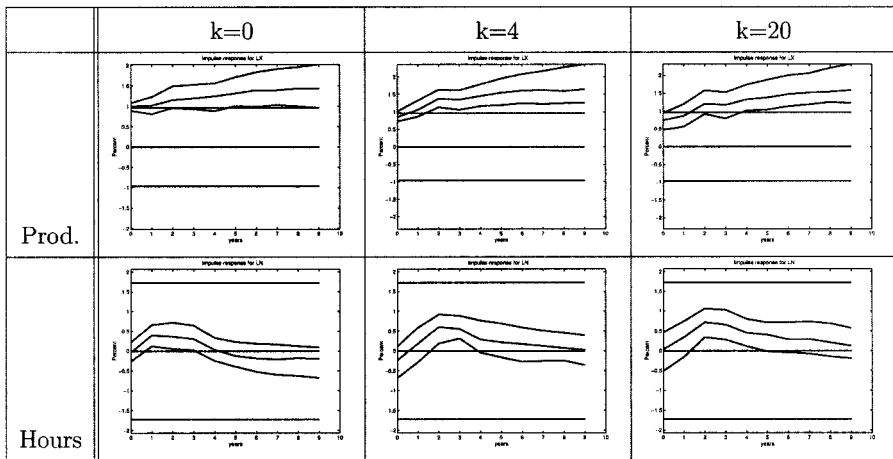


FIGURE 6. Impulse responses, postwar data. VAR in labor productivity, level labor and dividend tax rates. Shown are the median response as well as the 16% and the 86% quantiles.

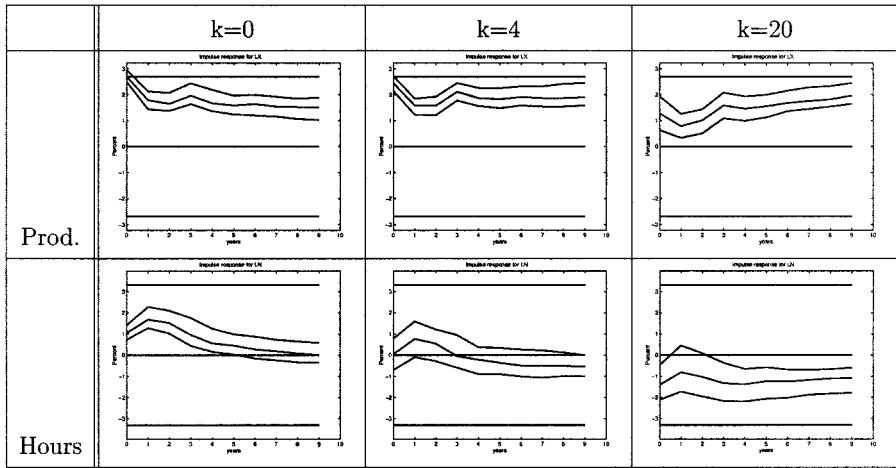


FIGURE 7. Impulse responses, data 1889–2002. VAR in labor productivity, level labor and dividend tax rates. Shown are the median response as well as the 16% and the 86% quantiles.

mildly positive following a near-zero initial response, regardless of the data set used.

5. Conclusions

In this paper, I have shed light on the debate of whether technology shocks lead to a fall in total hours worked, following up on the debate initiated by Galí (1999). I first provided a theory with capital income taxation, labor hoarding as well as long-run shifts in the social attitudes to the workplace to argue that there are other shocks that may influence labor productivity in the long run. In doing so, I have provided a novel way of modelling labor hoarding as “leisure at the workplace.”

I introduced “medium-run identification,” applied it to artificial data generated from theory and compared it both to long-run identification as in Galí (1999) and standard short-run Cholesky decompositions. According to the theory, neither short-run, medium-run, nor long-run identification will exactly identify the technology shock: The most one may hope for is to come close. I find that medium-run identification gets closest to replicating the true impulse response of total hours worked to a technology shock.

Applying it to data, I find that medium-run identification provides more robust results in a three-variable VAR in labor productivity, level labor, and dividend taxes than long-run identification. According to my estimates, I find

that technology shocks lead to a humpshaped response of total hours worked, which is mildly positive following a near-zero initial response.

References

- Basu, Susanto, John Fernald, and Miles Kimball (1999). "Are Technology Improvements Contractionary?" Board of Governors of the Federal Reserve System, International Finance Discussion Paper No. 625.
- Blanchard, Olivier J. and Danny Quah (1989). "The Dynamic Effects of Aggregate Demand and Supply Disturbances." *American Economic Review*, 79, 655–673.
- Burnside, Craig, Martin Eichenbaum, and Sergio Rebelo (1993). "Labor Hoarding and the Business Cycle." *Journal of Political Economy*, 101, 245–273.
- Christiano, Lawrence J., Martin Eichenbaum, and Charles Evans (2001). "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." NBER Working Paper No. 6455.
- Christiano, Lawrence J., Martin Eichenbaum, and Robert Vigfusson (2003). "What Happens After a Technology Shock?" Working paper, Northwestern University.
- Cooley, Thomas F. and Edward C. Prescott, eds. (1995). *Frontiers in Business Cycle Research*. Princeton University Press.
- Fisher, Jonas (2002). "Technology Shocks Matter." Federal Reserve Bank of Chicago Working Paper 2002-14.
- Francis, Neville and Valerie Ramey (2001). "Is the Technology-Driven Real Business Cycle Hypothesis Dead? Shocks and Aggregate Fluctuations Revisited." Working paper, University of California, San Diego, Department of Economics.
- Francis, Neville and Valerie Ramey (2003). "The Source of Historical Economic Fluctuations: An Analysis Using Long-Run Restrictions." Working paper, University of California, San Diego, Department of Economics.
- Galí, Jordi (1999). "Technology, Employment and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations?" *American Economic Review*, 89, 249–271.
- Hall, Robert (2003). "Wage Determination and Employment Fluctuations." Working paper, Stanford University.
- King, Robert and Sergio T. Rebelo (1999). "Resuscitating Real Business Cycles." In *Handbook of Macroeconomics*, Vol 1B, edited by John B. Taylor and Michael Woodford. Elsevier.
- Maliar, Lilia and Serguei Maliar (2003). "The Representative Consumer in the Neoclassical Growth Model with Idiosyncratic Shocks." *Review of Economic Dynamics*, 6, 362–380.
- Michelacci, Claudio and David Lopez-Salido (2003). "Technology Shocks and Job Flows." Working paper, CEMFI.
- Shea, John (1998). "What do Technology Shocks Do?" In *NBER Macroeconomics Annual 1998*, 275–310. Ben Bernanke and Julio Rotemberg, editors. MIT Press.
- Smets, Frank and Raf Wouters (2003). "Shocks and Frictions in U.S. Business Cycles: A Bayesian DSGE Approach." Working paper, European Central Bank.
- Uhlig, Harald (2003). "What Moves Real GNP?" Working paper, Humboldt University.

This article has been cited by:

1. Gert Peersman, Roland Straub. 2009. TECHNOLOGY SHOCKS AND ROBUST SIGN RESTRICTIONS IN A EURO AREA SVAR. *International Economic Review* 50:3, 727-750. [[CrossRef](#)]
2. Andrew J. Clarke, Alok Johri. 2009. PROCYCLICAL SOLOW RESIDUALS WITHOUT TECHNOLOGY SHOCKS. *Macroeconomic Dynamics* 13:03, 366. [[CrossRef](#)]
3. Fabio Canova, David Lopez-Salido, Claudio Michelacci. 2009. The effects of technology shocks on hours and output: a robustness analysis. *Journal of Applied Econometrics* n/a-n/a. [[CrossRef](#)]
4. DOMENICO J. MARCHETTI, FRANCESCO NUCCI. 2007. Pricing Behavior and the Response of Hours to Productivity Shocks. *Journal of Money, Credit and Banking* 39:7, 1587-1611. [[CrossRef](#)]
5. Susanto Basu, John G Fernald, Miles S Kimball. 2007. Are Technology Improvements Contractionary?. *American Economic Review* 96:5, 1418-1448. [[CrossRef](#)]
6. Werner Hölzl, Andreas Reinstaller. 2005. Sectoral and Aggregate Technology Shocks:Is There a Relationship?. *Empirica* 32:1, 45-72. [[CrossRef](#)]
7. Jordi Galí . 2004. On The Role of Technology Shocks as a Source of Business Cycles: Some New EvidenceOn The Role of Technology Shocks as a Source of Business Cycles: Some New Evidence. *Journal of the European Economic Association* 2:2-3, 372-380.
8. Lawrence J. Christiano , Martin Eichenbaum , Robert Vigfusson . 2004. The Response of Hours to a Technology Shock: Evidence Based on Direct Measures of TechnologyThe Response of Hours to a Technology Shock: Evidence Based on Direct Measures of Technology. *Journal of the European Economic Association* 2:2-3, 381-395.