Technology-Hours Debate and the Two Margnis of Labor Adjustment: What Happened Outside the U.S.?

Svetlana Rujin[1,2]

[1]RWI - Leibniz Institute for Economic Research*
[2]Ruhr University Bochum

Preliminary and incomplete

This version: 8 December 2017

Abstract

What is the direction of the short-run response of labor hours to a permanent technological innovation across world's largest economies? What is the main operating margin of labor adjustment after technology shock occurs? Are technology-induced labor market fluctuations relevant for business cycles? To answer these questions, I employ quarterly labor input measures computed by Ohanian and Raffo (2012) for G7 countries, spanning the years 1970 and 2016. Following Galí (1999), permanent technology shocks are identified from vector autoregressions (VARs) with long-run restrictions. Additionally, drawbacks associated with Galí's identification strategy are addressed by applying the Max Share identification technique suggested by Francis, Owyang, Roush, and DiCecio (henceforth FORD) (2014). While being different in magnitude across G7 countries, the results overwhelmingly support the view of contractionary impact effects of technology shocks on labor hours. Furthermore, following a technology shock, labor market adjustment along the intensive and extensive margins is heterogeneous across countries. While the short-run labor input adjustment to new technologies takes place along both margins in countries with greater flexibility of labor market structures, labor input adjustment relies heavily on the intensive margin in countries with more rigid labor market structures.

JEL Classification: O40; O57; E32; C32;

Keywords: Technology Shocks; Labor Markets; Business Fluctuations; Structural Identification

*All correspondence to: Svetlana Rujin, RWI, Hohenzollernstr. 1/3, 45128 Essen, Germany. E-mail address: svetlana.rujin@rwi-essen.de. Tel.: +49 201 8149 295.

1 INTRODUCTION

The direction of the short-run response of hours worked to technology shocks still remains an ambiguous issue in the debate between two competing classes of business cycle models - the RBC and the New Keynesian (NK) models. Since the publication of the seminal paper by Galí in 1999, business cycle literature faced an outbreak of empirical studies striving to find consensus on the technology-hours debate. However, the debate still seems to be unsettled, since depending on the estimation technique, specification of the model, and identification strategy of structural shocks, there is broad evidence supporting as well as disapproving Galí's original claim that technology shocks are contractionary on impact. Moreover, due to the limited availability of internationally harmonized labor input measures, the existing empirical literature mostly focuses on the U.S.

This study contributes to the technology-hours debate by providing empirical evidence on the dynamic responses of alternative measures of labor input for G7 countries using the recently updated, most comprehensive, consistent international dataset of quarterly labor input measures (Ohanian and Raffo, 2012). Furthermore, an important novelty in the current article is the analysis of the dynamic behavior of the two margins of labor adjustment following a technology shock - the extensive margin proxied by employment and the intensive margin proxied by hours per worker - in order to shed light on the technology-induced sources of labor market fluctuations. This, in addition to the multi-country approach, adds a new perspective to the multifaceted technology-hours debate. Namely, I explore cross-country heterogeneities in the transmission mechanism of technology shocks to the labor market and establish the link between the country's main operating margin of labor adjustment and the flexibility of working practices in place.

Several of the main conclusions are worth anticipating. First, in line with the results presented in Galí's (1999) seminal study, I provide evidence on the contractionary immediate response of hours worked following a technological innovation. Furthermore, the magnitude of the immediate drop in hours worked is heterogeneous across countries. In addition, the main operating margin of labor adjustment to technology shocks differs with respect to the degree of labor market flexibility. Thus, while more flexible labor markets operate through both the extensive and the intensive margins, less flexible labor markets rely greatly on the adjustment along the intensive margin.

The remainder of this paper is organized as follows. Section 2 provides business cycle statistics on international labor markets. Section 3 introduces the baseline empirical framework, the data, and the specifications of empirical VARs used in the current study. A detailed discussion of the results from impulse response analysis and robustness checks are presented in sections 4 and 5. Concluding remarks are provided in section 6.

2 DESCRIPTIVE STATISTICS ON INTERNATIONAL LABOR MARKETS

Next, I discuss business cycle properties of labor productivity and labor input (Table 3) as well as unconditional volatility of labor input over the business cycle together with cross-country labor market characteristics (Table 4) (tables are provoded in the Appendix).

Table 3 reports unconditional correlations of log first differences of labor productivity (hourly and per employee), labor input (in log first differences and detrended using a HP filter with a smoothing parameter of 1600 (HP)), and output (specified correspondingly) for G7 countries. Sample period for all time series is 1970:1-2016:4, except for measures of hours worked for the United Kingdom, which start in 1971:1. Panel (a) shows the cyclicality of productivity with respect to output. While being strongly procyclical, hourly productivity displays a stronger comovement with output in Euro area countries and a less pronounced procyclicality with respect to output in the U.S. and Canada. This, however, stands in stark contrast to the cyclical fluctuations in labor input. Thus, while total hours worked display a strong procyclicality in the U.S. and Canada, the positive comovement between total hours and output is weaker in the european coutries. A more interesting piece of evidence is, however, the difference in the cyclical properties between the two margins of labor input. While the correlation between employment and output is very strong in the U.S. and Canada, this holds for the european countries when one considers hours worked per employee. Finally, in accordance with the findings documented in Galí (1999), the correlation between hours and labor productivity is strongly negative. The same applies to the two margins of labor adjustment across all G7 countries.

Table 4 reports statistics on the unconditional volatility of labor input over the business cycle. Panel (a) shows that the output elasticity of labor input is higher in north-american countries, and especially so in the case of employment. The opposite holds to the european countries when considering the output elasticity of the intensive margin. In the same vein, the results in pael (b) point to the greater elasticity of labor input with respect to labor productivity for the U.S. and Canada. Regarding the margins of labor adjustment, while the elasticity of employment is weaker in europe, the latter group of countries displays a greater elasticity of hours per worker with respect to productivity when compared to the G7-average. This observation is clearly reflected in panel (c) displying the relative volatility of the extensive to the intensive margin.

Finally, the outcomes discussed above can be traced back to the differences in labor market structures across G7 countries. For this purpose, relevant labor market indicators are summarized in panel (d). These statistics make it clear, that the european labor market structures can be characterized as rigid relative to those in the U.S., the U.K., and Canada; With the working practices in the U.S. and those in Italy being on the opposite ends of the distribution.

3 EMPIRICAL FRAMEWORK

3.1 STRUCTURAL VECTOR AUTOREGRESSION MODEL

Since the application of structural VAR (SVAR) models has become standard practice in quantifying the impulse responses to technology shocks, measuring the degree of uncertainty about their dynamic effects as well as evaluating the contribution of technological innovations to fluctuations in the key variables of interest, I provide an overview of the related VAR-based empirical literature.

Recent studies employing VAR models have adopted two different identification approaches for recovering the structural equation parameters and consequently the economic shocks. The first identification strategy of structural shocks explicitly utilizes parametric restrictions by, e.g., imposing long-run zero restrictions on the moving average (MA) representation of the structural VAR (SVAR) model. Second, a more recent approach in empirical literature is to impose sign restrictions upon the impulse responses as a way of identifying economic shocks while leaving the structural parameters of the VAR unrestricted.

The empirical technology-hours debate has its origins in the seminal study by Galí (1999) on the role of technology shocks in explaining aggregate fluctuations. Galí finds that for the majority of the G7 countries there is a decline in labor input following a technology shock, which is in line with the predictions of a standard business cycle model with monopolistic competition and sticky prices and consequently raises doubts about the soundness of the RBC interpretation of aggregate fluctuations.

Among studies that use the standard parametric identification method to analyze the impact effects of stochastic technology shocks on labor input while utilizing a direct measure of technology, Basu et al. (2006) is the most prominent one. To do so, a utilization-corrected measure of total factor productivity (TFP) is used to serve as a proxy for exogenous technology shocks in a bivariate VAR setup. The impulse response analysis reveals that total hours worked fall sharply on impact following a technological improvement. In subsequent periods labor hours display an upward movement in response to a technology shock. Another example employing the parametric identification strategy while using the method of Basu et al. (2006) to correct the standard TFP for cyclical variations in unobserved utilization is Carlsson (2003). Using Swedish annual manufacturing data, impulse responses imply an immediate decline in hours worked following a technology shock and a rebound effect in subsequent periods.

Given that VAR-based studies employing different identification strategies result in conflicting findings on the short-run response of labor input to a positive technology shock, Christiano et al. (2004) perform an empirical exercise combining the methods presented above. Thus, the authors apply the long-run identification assumption as in Galí (1999) on the direct measure of technology developed in Basu et al. (2006). The result of this empirical exercise leads to the conclusion that hours worked rise in response to a technology shock. Consequently, while the long-run identification strategy is robust against the use of either labor productivity or utilization-corrected TFP to recover the shocks in technology, the results are sensitive to the differences in the data treatment.

A considerable body of recent studies contributing to the empirical technology-hours debate initiated by Galí (1999) analyzes the labor market dynamics induced by technology shocks using a structural vector autoregression (SVAR) approach. In this context, the debate still seems to be unsettled, since depending on the estimation technique, specification of the model, and identification strategy of structural shocks, there is broad evidence supporting as well as disapproving Galí's (1999) original claim that technology shocks have a contractionary impact effect on labor input.

Cross-country baseline results are derived from bivariate VARs for labor productivity and a measure of labor input and are provided in the appendix along with the supporting statistics.

Following Galí (1999), technology shocks are identified by imposing a lower-triangular structure on the matrix of the long-run multipliers, i.e., assuming that only technology shocks may have a permanent effect on the level of productivity. Furthermore, I address the drawbacks associated with this identification strategy - misspecification and accuracy of identification assumptions - by imposing medium-run restrictions. Following FORD (2014), technology shock is identified as the shock that maximizes the forecast error variance share of labor productivity at some finite horizon (h) (Max Share identification technique).

[To be completed later]

3.2 DATA AND EMPIRICAL MODEL

I employ the recently updated quarterly data on alternative measures of labor input - per capita hours, employment, hours worked per worker, and total hours for G7 countries, spanning from 1970 to 2016, computed by Ohanian and Raffo. Measures of labor productivity, hourly and per employee, are computed by subtracting the latter from the log of real GDP, respectively.

[To be completed later]

4 EMPIRICAL RESULTS

Cross-country baseline results are derived from bivariate VARs for labor productivity and a measure of labor input and are provided in the appendix along with the supporting business cycle statistics.

[To be completed later]

5 SENSITIVITY ANALYSIS

The sensitivity of the baseline results is tested against a different stochastic transformation of labor input (first differenced against HP-filtered) and the specification of lag structure.

Given the well-documented shortcomings associated with the identification of technology shocks by applying zero long-run restrictions, an alternative middle-run identification strategy is utilized.

[To be completed later]

6 CONCLUSION

This article makes two contributions. The first is to exploit the impact effects of technology shocks on labor hours in a multi-country framework. The second is to consider the sources of labor adjustment to new technologies while focusing on the extensive and the intensive labor input margins. Furthermore, cross-country heterogeneities in the adjustment of labor input following a technology shocks are traced back to different labor market structures in place.

The results of the study support the view of contractionary short-run effects of technology shocks on labor input, which is in line with the growing body of recent empirical evidence on the issue. However, the sources of these fluctuations differ across countries. These heterogeneities in the labor market adjustment to technology shocks can be traced back to the differences in labor market structures and their degree of flexibility to adjust to new economic conditions.

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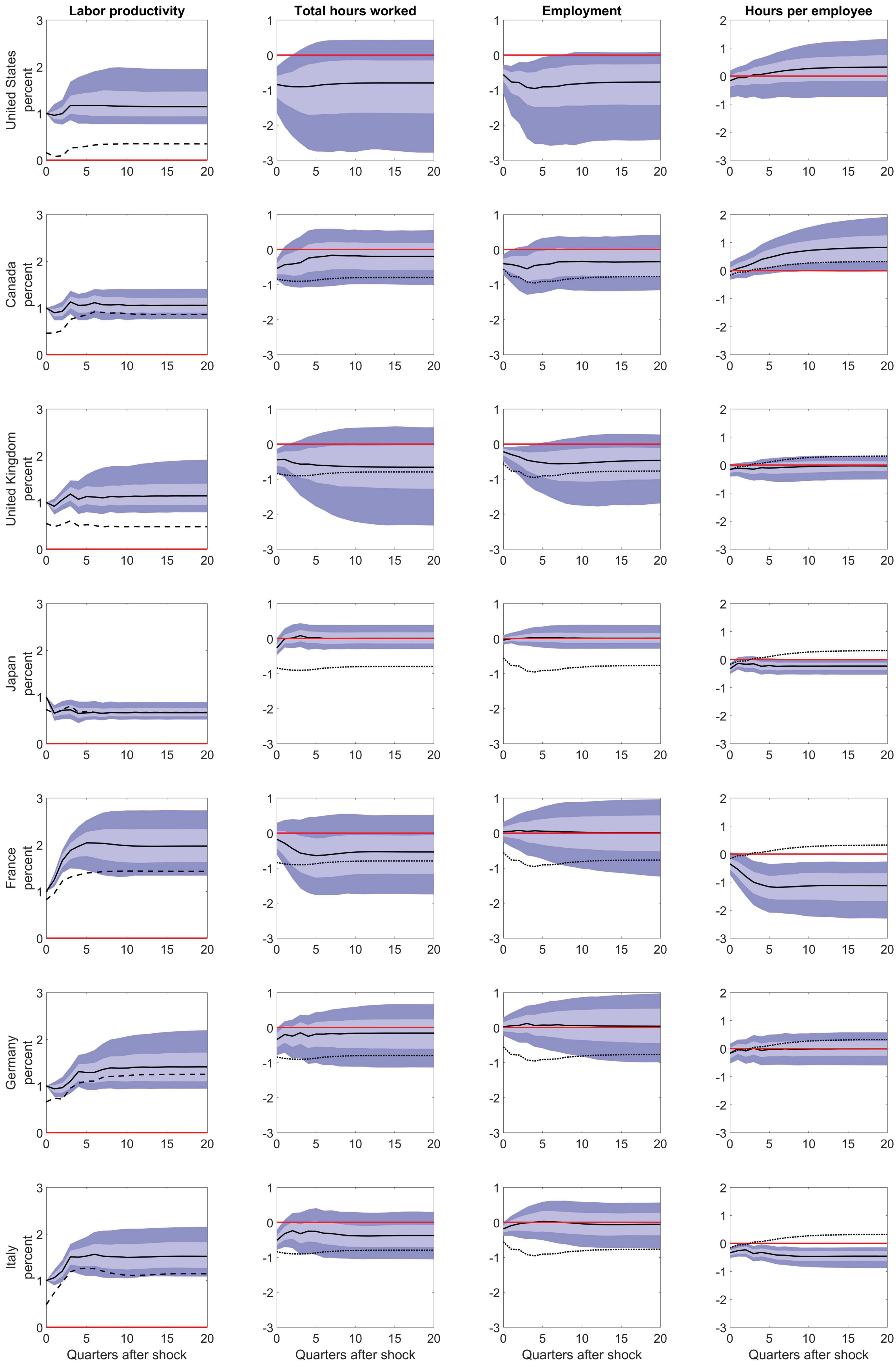

Figure 1: Impulse responses to technology shock (Galí model)

Table 1: Unit root tests

International data on labor input

		Total hours		Total hours (demogr. adj.)		Employment		Hours per worker	
		level	Δ	level	Δ	level	Δ	level	Δ
Canada	ADF	-2.37	-8.64**	-3.34	-8.38**	-2.23	-4.83**	-2.42	-14.22**
	KPSS	0.26**	0.03	0.08	0.04	0.26**	0.07	0.18*	0.12
France	ADF	-2.22	-6.74**	-1.67	-7.15**	-2.54	-4.62**	-2.17	-7.15**
	KPSS	0.39**	0.05	0.36**	0.06	0.22**	0.07	0.33**	0.03
Germany	ADF	-1.48	-7.79**	-1.06	-7.91**	-2.95	-5.79**	-1.31	-16.43**
	KPSS	0.23**	0.04	0.40**	0.03	0.09	0.05	0.41**	0.02
Italy	ADF	-0.91	-11.93**	-2.66	-11.56**	-1.85	-5.94**	-2.53	-16.83**
	KPSS	0.27**	0.07	0.12	0.07	0.25**	0.05	0.20*	0.15*
Japan	ADF	-1.14	-16.43**	-1.71	-16.57**	-0.89	-6.82**	-2.04	-18.00**
	KPSS	0.39**	0.09	0.13	0.09	0.39**	0.13	0.21*	0.06
United Kingdom	ADF	-2.37	-4.70**	-2.55	-4.65**	-2.70	-4.69**	-1.87	-16.23**
	KPSS	0.26**	0.03	0.18*	0.04	0.29**	0.03	0.17*	0.05
United States	ADF	-1.38	-8.35**	-2.33	-8.08**	-1.48	-7.10**	-2.88	-13.06**
	KPSS	0.37**	0.05	0.30**	0.08	0.40**	0.04	0.16*	0.12

Notes: ADF t-statistics for the null hypothesis of a unit root and KPSS LM-statistics for the null hypothesis that the data are stationary. Time series are specified in log-levels and log first differences. Test equations include an intercept and a time trend. Lags for the ADF test equations were chosen optimally based on SIC up to max=12 and the maximum lag order for KPSS tests was chosen from an automatic bandwidth selection routine. * (**) indicate rejection at 5 (1) percent level. Sample period for all time series is 1970:1-2016:4, except for measures of hours worked for the United Kingdom, which start in 1971:1. Data source: Ohanian and Raffo (2012); http://andreararaffo.com/araffo/Research.html.

Table 2: Unit Root Tests

International data on output and labor productivity

		Output		Hourly labor productivity		Employee labor productivity	
		level	Δ	level	Δ	level	Δ
Canada	ADF	-2.75	-8.59**	-2.95	-15.88**	-2.00	-5.53**
	KPSS	0.19*	0.05	0.12	0.05	0.17*	0.06
France	ADF	-1.48	-6.92**	-2.04	-6.89**	-2.67	-7.57**
	KPSS	0.34**	0.06	0.43**	0.05	0.44**	0.10
Germany	ADF	-2.20	-12.32**	-1.19	-16.15**	-1.83	-13.95**
	KPSS	0.38**	0.03	0.40**	0.06	0.37**	0.04
Italy	ADF	-0.45	-8.42**	-2.64	-13.93**	-1.14	-13.15**
	KPSS	0.41**	0.04	0.42**	0.09	0.43**	0.05
Japan	ADF	-1.08	-12.70**	-1.65	-20.05**	-1.66	-14.59**
	KPSS	0.42**	0.07	0.44**	0.05	0.45**	0.04
United Kingdom	ADF	-2.19	-7.04**	-0.02	-14.52**	-0.71	-13.31**
	KPSS	0.16*	0.06	0.35**	0.10	0.35**	0.06
United States	ADF	-1.11	-9.93**	-1.72	-14.50**	-1.92	-13.95**
	KPSS	0.29**	0.06	0.25**	0.10	0.25**	0.14

Notes: ADF t-statistics for the null hypothesis of a unit root and KPSS LM-statistics for the null hypothesis that the data are stationary. Time series are specified in log-levels and log first differences. Test equations include an intercept and a time trend. Lags for the ADF test equations were chosen optimally based on SIC up to max=12 and the maximum lag order for KPSS tests was chosen from an automatic bandwidth selection routine. * (**) indicate rejection at 5 (1) percent level. Sample period for all time series is 1970:1-2016:4, except for hourly labor productivity for the United Kingdom, which starts in 1971:1. Data source: Ohanian and Raffo (2012); http://andrearaffo.com/araffo/Research.html.

Table 3: Cyclical properties of labor productivity and labor input

International evidence

		United States	Canada	United Kingdom	Japan	France	Germany	Italy	Avg. (G7)	Avg. (EU countries)
		a. Cyclicality of productivity with respect to output								
Hourly productivity	Δ	0.53**	0.51**	0.78**	0.73**	0.72**	0.76**	0.65**	0.67	0.71
Employee productivity	Δ	0.79**	0.71**	0.90**	0.95**	0.93**	0.93**	0.88**	0.87	0.91
		b. Cyclicality of labor input with respect to output								
Per capita hours	Δ	0.60**	0.57**	0.37**	0.13	0.26**	0.44**	0.45**	0.40	0.38
	HP	0.86**	0.83**	0.72**	0.67**	0.53**	0.78**	0.65**	0.72	0.65
Employment	Δ	0.58**	0.63**	0.34**	0.28**	0.57**	0.36**	0.48**	0.46	0.47
	HP	0.82**	0.78**	0.57**	0.53**	0.80**	0.63**	0.66**	0.69	0.70
Hours per worker	Δ	0.44**	0.24**	0.22**	0.12	0.05	0.39**	0.28**	0.25	0.24
	HP	0.77**	0.65**	0.74**	0.57**	0.11	0.48**	0.37**	0.53	0.32
		c. Unconditional correlation of productivity with labor input								
Per capita hours	Δ	-0.33**	-0.38**	-0.28**	-0.56**	-0.42**	-0.20**	-0.38**	-0.36	-0.33
	HP	-0.28**	-0.28**	-0.27**	-0.24**	-0.08	-0.08	-0.24**	-0.21	-0.13
Employment	Δ	-0.05	-0.10	-0.11	-0.04	0.24**	0.00	0.00	-0.11	0.08
	HP	-0.30**	-0.31**	-0.33**	-0.28**	-0.12	-0.10	-0.25**	-0.24	-0.16
Hours per worker	Δ	-0.30**	-0.43**	-0.28**	-0.53**	-0.60**	-0.19**	-0.40**	-0.39	-0.40
	HP	-0.30**	-0.27**	-0.29**	-0.22**	-0.10	-0.13	-0.14	-0.21	-0.12

Notes: This table reports unconditional correlations of log first differences of labor productivity (hourly and per employee), labor input (in log first differences (Δ) and detrended using a HP filter with a smoothing parameter of 1600 (HP)), and output (specified correspondingly) for G7 countries. Sample period for all time series is 1970:1-2016:4, except for measures of hours worked for the United Kingdom, which start in 1971:1. Data source: Ohanian and Raffo (2012); http://andrearaffo.com/araffo/Research.html.

Table 4: Unconditional volatility of labor input over the business cycle

International evidence

		United States	Canada	United Kingdom	Japan	France	Germany	Italy	Avg. (G7)	Avg. (EU countries)
a. Volatility of labor input relative to output										
Per capita hours	Δ	0.89	0.94	0.66	0.79	0.89	0.74	0.82	0.82	0.81
	HP	1.01	1.04	0.83	0.70	0.93	0.71	0.81	0.86	0.82
Employment	Δ	0.62	0.71	0.44	0.32	0.37	0.36	0.48	0.47	0.41
	HP	0.72	0.76	0.60	0.33	0.52	0.57	0.54	0.58	0.54
Hours per worker	Δ	0.36	0.37	0.41	1.48	0.73	0.61	0.66	0.66	0.66
	HP	0.38	0.36	0.35	0.53	0.70	0.40	0.40	0.45	0.50
b. Volatility of labor input relative to productivity										
Per capita hours	Δ	1.09	1.12	0.68	0.70	0.85	0.85	0.88	0.88	0.86
	HP	2.30	2.26	1.48	0.85	1.61	1.26	1.39	1.59	1.42
Employment	Δ	0.76	0.91	0.46	0.34	0.44	0.39	0.55	0.55	0.46
	HP	1.64	1.77	1.09	0.47	1.12	0.95	0.99	1.15	1.02
Hours per worker	Δ	0.59	0.61	0.44	0.60	0.65	0.61	0.61	0.59	0.63
	HP	0.86	0.79	0.62	0.65	1.22	0.72	0.68	0.79	0.87
c. Relative volatility of the extensive to the intensive margin										
Ratio (with respect to output)	Δ	1.72	1.91	1.07	0.22	0.51	0.59	0.73	0.96	0.61
	HP	1.89	2.08	1.70	0.62	0.74	1.42	1.36	1.40	1.17
Ratio (with respect to productivity)	Δ	1.29	1.50	1.06	0.56	0.68	0.63	0.90	0.95	0.74
	HP	1.90	2.26	1.75	0.73	0.92	1.32	1.45	1.48	1.23
d. Labor market indicators										
Labor market efficiency, WEF		5.57	5.32	5.31	4.99	4.28	4.47	3.59	4.79	4.11
Hiring and firing practices, 1-7 (best), WEF		5.14	4.59	4.35	3.06	2.64	2.82	2.58	3.60	2.68
Strictness of employment protection (OECD)		0.26	0.92	1.17	1.62	2.39	2.65	2.76	1.68	2.60
Flexibility of wage determination, 1-7 (best), WEF		5.65	5.51	5.77	5.84	4.93	3.12	3.18	4.86	3.74
Pay and productivity, 1-7 (best), WEF		5.01	4.57	4.71	4.83	4.06	4.34	2.99	4.36	3.80

Notes: This table reports ratios of standard deviations of labor input measures (in log first differences (Δ) and detrended using a HP filter with a smoothing parameter of 1600 (HP)) to the standard deviation of output (in log first differences and detrended, respectively) - panel (a) - and labor productivity (hourly and per employee, in log first differences) - panel (b). Sample period is 1970:1-2016:4; measures of hours worked for the United Kingdom start in 1971:1. Panel (c) reports the ratios of relative standard deviations of labor input along the extensive margin (employment) to relative standard deviations of labor input along the intensive margin (hours per worker), based on statistics from (a) and (b). Panel (e) reports cross-country averages of labor market indicatiors provided by the World Economic Forum (WEF) and the OECD for the time period 2006-2016 and 1985-2013, respectively. OECD index on the strictness of employment protection (EPRC_V1) concerns regulations for individual dismissals related to regular contracts. Data source for labor input measures and output: Ohanian and Raffo (2012); http://andrearaffo.com/araffo/Research.html.

Table 5: Estimates of conditional correlations between productivity and labor input

International evidence

	United States	Canada	United Kingdom	Japan	France	Germany	Italy	Avg. (G7)	Avg. (EU countries)
					Per capita hours				
$cor(\Delta z_h, \Delta l \mid \varepsilon^z)$	-0.979**	-0.974**	-0.978**	-0.898**	-0.995**	-0.944**	-0.891**	-0.951	-0.943
	(0.036)	(0.076)	(0.097)	(0.133)	(0.177)	(0.182)	(0.151)		
$cor(\Delta z_h, \Delta l \mid \varepsilon^l)$	0.367**	0.340*	0.426**	-0.456	0.325	0.744**	0.513	0.323	0.527
	(0.130)	(0.194)	(0.154)	(0.406)	(0.550)	(0.317)	(0.412)		
$cor(\Delta z_h, l_{HP} \mid \varepsilon^z)$	-0.662**	-0.489**	-0.557**	-0.670**	-0.205	-0.426	-0.864**	-0.553	-0.498
	(0.158)	(0.088)	(0.113)	(0.231)	(0.575)	(0.260)	(0.124)		
$cor(\Delta z_h, l_{HP} \mid \varepsilon^l)$	-0.417**	-0.043	-0.234*	-0.063	-0.236	0.199	0.301	-0.070	0.088
	(0.127)	(0.143)	(0.129)	(0.202)	(0.303)	(0.266)	(0.277)		
					Employment				
$cor(\Delta z_e, \Delta l \mid \varepsilon^z)$	-0.775**	-0.807**	-0.988**	0.189	0.487	-0.929**	-0.474	-0.471	-0.305
	(0.256)	(0.287)	(0.214)	(0.331)	(0.540)	(0.372)	(0.430)		
$cor(\Delta z_e, \Delta l \mid \varepsilon^l)$	0.496**	0.629**	0.397**	-0.654*	0.513*	0.468**	0.466	0.331	0.482
	(0.117)	(0.231)	(0.110)	(0.382)	(0.273)	(0.205)	(0.320)		
$cor(\Delta z_e, l_{HP} \mid \varepsilon^z)$	-0.581**	-0.559**	-0.510**	-0.767**	0.169	-0.232	-0.785**	-0.466	-0.283
	(0.094)	(0.087)	(0.101)	(0.063)	(0.342)	(0.251)	(0.118)		
$cor(\Delta z_e, l_{HP} \mid \varepsilon^l)$	-0.225**	-0.063	-0.309**	0.154	-0.515**	-0.283	0.014	-0.175	-0.261
	(0.083)	(0.099)	(0.115)	(0.119)	(0.190)	(0.176)	(0.177)		
					Hours per worker				
$cor(\Delta z_h, \Delta l \mid \varepsilon^z)$	-0.948**	-0.926**	-0.839**	-0.717**	-0.994**	-0.898**	-0.863**	-0.884	-0.918
	(0.068)	(0.131)	(0.286)	(0.250)	(0.091)	(0.145)	(0.126)		
$cor(\Delta z_h, \Delta l \mid \varepsilon^l)$	0.782**	-0.223	0.033	-0.776**	-0.708	0.756**	-0.304	-0.063	-0.085
	(0.137)	(0.416)	(0.478)	(0.224)	(0.439)	(0.305)	(0.382)		
$cor(\Delta z_h, l_{HP} \mid \varepsilon^z)$	-0.723**	-0.707**	-0.728**	-0.333	0.018	-0.629**	-0.718*	-0.546	-0.443
	(0.130)	(0.112)	(0.077)	(0.327)	(0.409)	(0.238)	(0.424)		
$cor(\Delta z_h, l_{HP} \mid \varepsilon^l)$	0.015	0.455*	0.262**	-0.265	-0.196	0.204	-0.212	0.038	-0.068
	(0.244)	(0.234)	(0.121)	(0.190)	(0.164)	(0.279)	(0.282)		

Notes: This table reports conditional correlations between log first differences of labor productivity (hourly (Δz_h) and per employee (Δz_e)) and labor input (in log first differences (Δl) and detrended using a HP filter with a smoothing parameter of 1600) (l_{HP})), estimated from bivariate VARs (as originally proposed by Galí, 1999) for G7 countries. Technology shocks were normalized to produce a contemporaneous unit increase in productivity. Standard errors are shown in parantheses. The asteriscks * (**) indicate statistical significance at 10 (5) percent level. Sample period for all time series is 1970:1-2016:4, except for measures of hours worked for the United Kingdom, which start in 1971:1. Data source: Ohanian and Raffo (2012); http://andrearaffo.com/araffo/Research.html.

Table 6: Summary of the impact responses of labor input measures to a technology shock

International evidence

	Per capita hours		Employment		Hours per worker		Total hours	
	Δ	HP	Δ	HP	Δ	HP	Δ	HP
United States	-0.981**	-0.424**	-0.269*	-0.430**	-0.388**	-0.283**	-0.931**	-0.437**
	(0.333)	(0.204)	(0.156)	(0.193)	(0.135)	(0.122)	(0.322)	(0.198)
Canada	-0.634**	-0.689**	-0.246*	-0.596**	-0.263**	-0.330**	-0.531**	-0.652**
	(0.179)	(0.178)	(0.137)	(0.214)	(0.102)	(0.115)	(0.175)	(0.177)
United Kingdom	-0.490**	-0.316**	-0.217*	-0.216**	-0.135	-0.316**	-0.488**	-0.320**
	(0.220)	(0.138)	(0.117)	(0.107)	(0.089)	(0.109)	(0.214)	(0.138)
Japan	-0.331**	-0.257**	0.014	-0.251**	-0.164*	-0.108	-0.135	-0.270**
	(0.112)	(0.114)	(0.060)	(0.082)	(0.094)	(0.103)	(0.121)	(0.101)
France	-0.382**	-0.026	0.002	-0.014	-0.331**	0.003	-0.324**	-0.095
	(0.155)	(0.201)	(0.064)	(0.049)	(0.120)	(0.112)	(0.132)	(0.130)
Germany	-0.412**	-0.267*	-0.116	-0.050	-0.298**	-0.199*	-0.357*	-0.258
	(0.206)	(0.158)	(0.107)	(0.071)	(0.133)	(0.110)	(0.188)	(0.163)
Italy	-0.555**	-0.477**	-0.185	-0.328**	-0.291**	-0.124	-0.505**	-0.456**
	(0.141)	(0.130)	(0.129)	(0.095)	(0.090)	(0.106)	(0.138)	(0.128)
	Averages							
G7	-0.541	-0.351	-0.145	-0.269	-0.267	-0.194	-0.467	-0.357
EU countries	-0.450	-0.257	-0.100	-0.131	-0.307	-0.107	-0.395	-0.270

Notes: This table reports the estimates of the immediate responses of alternative measures of labor input (specified in log first differences (Δ) or detrended (HP) (using a HP filter with a smoothing parameter of 1600) to a 1-percent improvement in technology. Following Galí (1999), a positive technology shock is identified from a bivariate SVAR with long-run restrictions. Standard errors are shown in parantheses. The asteriscks * (**) indicate statistical significance at 10 (5) percent level. Sample period for all time series is 1970:1-2016:4, except for measures of hours worked for the United Kingdom, which start in 1971:1. Data source: Ohanian and Raffo (2012); http://andrearaffo.com/araffo/Research.html.

Table 7: Summary of the impact responses of labor input measures to a demand shock

International evidence

	Per capita hours		Employment		Hours per worker		Total hours	
	Δ	HP	Δ	HP	Δ	HP	Δ	HP
United States	0.345**	0.468**	0.334**	0.255**	0.285**	0.285**	0.370**	0.478**
	(0.086)	(0.074)	(0.037)	(0.046)	(0.041)	(0.040)	(0.089)	(0.074)
Canada	0.433**	0.352**	0.369**	0.240**	0.348**	0.284**	0.471**	0.363**
	(0.062)	(0.072)	(0.032)	(0.043)	(0.031)	(0.042)	(0.060)	(0.068)
United Kingdom	0.315**	0.337**	0.215**	0.189**	0.344**	0.231**	0.311**	0.332**
	(0.075)	(0.055)	(0.033)	(0.031)	(0.031)	(0.048)	(0.072)	(0.052)
Japan	0.711**	0.653**	0.302**	0.184**	0.659**	0.597**	0.769**	0.642**
	(0.074)	(0.069)	(0.021)	(0.037)	(0.056)	(0.050)	(0.058)	(0.067)
France	0.356**	0.350**	0.091**	0.081**	0.257**	0.260**	0.261**	0.265**
	(0.066)	(0.055)	(0.007)	(0.006)	(0.035)	(0.039)	(0.034)	(0.036)
Germany	0.599**	0.543**	0.227**	0.213**	0.450**	0.403**	0.551**	0.502**
	(0.066)	(0.048)	(0.029)	(0.018)	(0.039)	(0.034)	(0.055)	(0.049)
Italy	0.516**	0.480**	0.334**	0.251**	0.423**	0.406**	0.529**	0.478**
	(0.068)	(0.062)	(0.029)	(0.033)	(0.034)	(0.031)	(0.063)	(0.061)
	Averages							
G7	0.468	0.455	0.267	0.202	0.395	0.352	0.466	0.437
EU countries	0.490	0.458	0.217	0.182	0.377	0.356	0.447	0.415

Notes: This table reports the estimates of the immediate responses of alternative measures of labor input (specified in log first differences (Δ) or detrended (HP) (using a HP filter with a smoothing parameter of 1600) to a demand shock. Standard errors are shown in parantheses. The asteriscks * (**) indicate statistical significance at 10 (5) percent level. Sample period for all time series is 1970:1-2016:4, except for measures of hours worked for the United Kingdom, which start in 1971:1. Data source: Ohanian and Raffo (2012); http://andreraffo.com/araffo/Research.html.

Table 8: Summary of the impact responses of labor input to a technology shock (3-variable VARs); International evidence

	Hours per worker		Employment	
	Δ	HP	Δ	HP
United States	-0.513**	-0.135	-0.450**	-0.289**
	(0.192)	(0.119)	(0.217)	(0.124)
Canada	-0.246**	-0.252**	-0.207	-0.291**
	(0.100)	(0.122)	(0.127)	(0.115)
United Kingdom	-0.197*	-0.126	-0.217**	-0.036
	(0.114)	(0.083)	(0.101)	(0.066)
Japan	-0.146	-0.193**	0.030	-0.149**
	(0.098)	(0.086)	(0.056)	(0.052)
France	-0.311**	0.081	0.024	-0.006
	(0.120)	(0.148)	(0.050)	(0.048)
Germany	-0.271*	-0.268**	-0.002	-0.069
	(0.140)	(0.121)	(0.087)	(0.072)
Italy	-0.323**	-0.083	-0.173*	-0.280**
	(0.080)	(0.120)	(0.105)	(0.093)
	Averages			
G7	-0.287	-0.139	-0.142	-0.160
EU countries	-0.302	-0.090	-0.050	-0.118

Notes: This table reports the estimates of the immediate responses of alternative measures of labor input (specified in log first differences (Δ) or detrended (HP) (using a HP filter with a smoothing parameter of 1600) to a technology shock from a three-variable VAR model for hourly labor productivity, hours worked per employee, and employment (ordered last). Standard errors are shown in parantheses. The asteriscks * (**) indicate statistical significance at 10 (5) percent level. Sample period for all time series is 1970:1-2016:4, except for measures of hours worked for the United Kingdom, which start in 1971:1. Data source: Ohanian and Raffo (2012); http://andrearaffo.com/araffo/Research.html.