Sectoral effects of corporate taxation in OECD countries

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Abstract

By developing a new identification of exogenous and permanent changes in corporate taxation, we explore its dynamic effects on labor and innovation which appear to vary widely across countries and sectors. This SVAR identification is based on the downward trend of corporate tax rates observed in OECD countries which is rooted in international competition to attract capital following the removal of capital controls. Our SVAR evidence for a panel of eleven OECD countries over 1973-2017 reveals that following a decline in profits' taxation, technology improvements are concentrated in traded industries while labor growth originates from non-traded industries. When we split our sample of eleven OECD countries into two sub-samples, we find empirically that continental European countries increase significantly labor while hours worked is essentially unchanged in English-speaking and Scandinavian countries. By contrast, lower corporate taxes encourage traded firms in English-speaking and Scandinavian countries to increase innovation, as captured by a permanent rise in utilization-adjusted-total factor productivity while innovation remains unchanged in continental European countries. Time series on the stock of R&D at a sectoral level corroborate these findings as only the stock of ideas in the traded sector of English-speaking and Scandinavian countries increases significantly following a permanent tax cut. In line with our model's predictions, a corporate tax cut increases labor in countries with sticky wages and has an expansionary effect on innovation in countries where the cost of innovating is low.

Keywords: Corporate taxes; VAR; Tradables and non-tradables; Endogenous technological change; R&D; Wage Stickiness

JEL Codes: E23; E62; F11; F41; H25; O33

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1 Introduction

The average corporate income tax rate has dropped from 50% in 1970 to 32.5% in 2000 and has settled at 23.9% in 2018 in advanced economies. According to Devereux et al. (2002) such a downward trend is rooted in the competition to attract capital as OECD countries has removed capital controls in the 1980s. In this regard, a large span of the literature related to corporate taxation has highlighted that the combined effect of increased economic integration and international tax competition has reduced statutory tax rates in rich countries (see e.g., Zucman, 2014). In this research, we propose to investigate empirically the dynamic effects of such a downward trend of corporate tax rates in OECD countries on innovation and employment.

By increasing the return on innovation activities, low corporate tax rates can potentially increase utilization-adjusted-total factor productivity (TFP) which is a major driver of economic growth. The macroeconomics literature has highlighted this strong link in the U.S. data, see e.g., Akcigit et al. (2022), Cloyne et al. (2022). While corporate tax cuts can potentially have a significant and positive effect on technological change, they can also provide an incentive to reallocate resources across sectors. In this regard, advanced countries' production structure is characterized by highly innovative (mainly exporting) and labor-intensive industries (mostly non-exporting). Because firms' production adjustment to the corporate tax cut will differ across sectors, productive resources, especially labor, will shift across sectors. In this research, we provide an attempt to answer the question: Do corporate tax cuts increase innovation and labor uniformly across sectors and across countries? It is essential to quantify their impact as so far, to our knowledge, the effects of corporate tax cuts have not been contrasted between OECD (or group of OECD) countries and have not been investigated at a sectoral level, except on U.S. data.

One major challenge is to identify exogenous variations in corporate tax rates, i.e., variations in tax rates that are exogenous to the current state of the economy. Most of the papers in the literature use narratively identified tax changes based on the policy changes in governments' sources. The narratively identified shocks are only available for a few countries, and the standard for choosing exogenous changes to taxation may not be completely reliable, as decision-makers could assert that their only focus is on the long-term shortage or the public debt level, when in truth they may be reacting to various temporary factors, see Perotti (2012). Because we want to compare the effects across countries or groups of OECD countries and are interested in the impact of corporate tax cuts on innovation which is a long-term growth issue, it is essential to propose a simple and robust identification of highly persistent changes in tax rates which allows international comparisons.

In this regard, one key contribution of our paper is to propose a new identification scheme of permanent corporate tax cuts based on the existence of common downward trend in corporate tax rates driven by international tax competition. Because the international component of tax rates is not correlated with country-specific economic activity, our identification approach avoids any potential endogeneity issue with economic activity within the same year. Tax levels of countries are positively related to taxes of other countries and especially close countries like neighbours (Davies and Voget, 2009). To capture more accurately the degree of international competition faced by each country, we construct an international tax rate for each country by considering the trade intensity between the home country and its trade partner within eleven countries as a weight. The most important feature of this tax measure is that it does not contain the country's own corporate tax rate. This property strengthens the exogeneity of the international tax rate to the country's economic conditions. The assumption of international tax competition paves the way for the identification of exogenous (and permanent) corporate tax cuts as this hypothesis ensures that the tax rates display a clear downward trend which is common across countries. Our sample will include eleven OECD countries over the period 1973-2017 as the corporate income tax is available over a long enough time horizon for these countries which also share the existence of a common downward trend (on which we base our identification approach). We will take advantage of our identification to compare the effects of corporate tax cuts between groups of OECD countries.

This research investigates whether corporate tax cuts boost innovation or employment or both in OECD countries. We conduct this analysis at a sectoral level by considering exporting and non-exporting sectors. This dichotomy is particularly suited to the investigation of the effects of corporate tax cuts which has a strong open economy dimension. By increasing the return on innovation and lowering the cost of capital, it is natural to expect that a decline in corporate tax rates result in an increase in investment in intangible and tangible assets along with a rise in employment. In this work, we investigate the impact of a decline in corporate taxation on utilization-adjusted-TFP, and hours worked. Our results show that a cut in corporate income taxation positively influences labor and aggregate output for the whole sample. Although the output is positively affected in traded and non-traded sectors, exporting firms increase utilization-adjusted-total factor productivity, whereas non-exporting firms increase hours worked.

We hypothesize that the effects of corporate taxation on utilization-adjusted TFP vary widely across countries. International differences in the innovation effects of a tax cut can be the result of differences in the costs of transforming R&D expenditure into ideas. Differently, international differences in the employment effects will depend on the extent of wage stickiness caused by labor market regulations. When we apply a clustering analysis based on several dimensions of labor market regulation such as the collective bargaining coverage, the centralization of wage bargaining and minimum wage legislation, we find that continental European countries display more regulated labor markets which can potentially generate wage stickiness. Therefore, we perform a split-sample analysis and investigate the effects of corporate tax shock for the two groups of countries: continental European countries (including Austria, Belgium, France, and Germany) on one hand and English-Speaking (Australia, the UK, the US) and Scandinavian countries (Finland, Sweden) plus Japan and Luxembourg on the other. Indeed, our SVAR evidence reveals that a corporate tax cut increases wages in the latter group of countries while wages remain essentially unchanged at all horizons in Continental European countries.

We assess empirically the impact of a corporate tax cut on technology and labor at a sectoral level by differentiating between English-speaking and Scandinavian countries on one hand and continental European countries on the other. Our results reveal that following a decline in profits' taxation, firms in the traded sector significantly use more labor in continental European countries while exporting firms in English-speaking and Scandinavian countries do not increase labor in the long run. By contrast, lower corporate taxes encourage traded firms in English-speaking and Scandinavian countries to increase innovation, as captured by a permanent rise in utilization-adjusted-total factor productivity. Our suggested mechanism is as follows: A fall in profits' taxation lowers the cost of physical capital and increases the return on intangible assets. Higher investment increases the demand for labor. Traded industries have strong incentives to increase investment in both assets because they are intensive in capital and R&D. Differently, the rise in labor demand will be prioritized in non-traded industries because they are labor intensive. Lower profits' taxation thus contributes to deindustrialization by shifting labor away from traded industries and toward non-traded industries. While our results corroborate our predictions for non-traded industries for both English speaking/Scandinavian countries and European economies, the effects are quite distinct for traded industries. While innovation rises in the first group, labor significantly increases in the latter group of countries. We conjecture that the cost of transforming R&D expenditure in innovation is larger in continental Europe, thus explaining why utilization adjusted TFP does not increase. By curbing the rise in the labor cost, wage stickiness may rationalize the rise in labor in this group of countries. When we run the regression of (logged) utilization-adjusted-TFP on the (logged) stock of R&D for tradables and non-tradables, respectively, we find that only the stock of R&D in the traded sector and in English-Speaking and Scandinavian countries increases significantly utilization-adjusted-traded-TFP while the elasticity of non-traded technology with respect to its stock of R&D is low and not significant.

The article is structured as follows. In section 2, we document the data and methodology that we use in the Panel SVAR analysis. In section 3, we show the VAR evidences for comparison with narrative approach, sectoral differences and international differences. In this section, we also provide evidence on the effect of corporate taxation on the structural change and labor income share. Section 4 discusses the robustness checks we have conducted (detailed in Online Appendix), w.r.t. the classification of industries, the construction of capital stock at a sectoral level, the SVAR identification of corporate tax shocks (including an exogeneity test), the measure of technology.

Literature review:

There are various studies about the effect of corporate tax rates on the labor market, innovation, and welfare. Mertens and Ravn (2013) use narrative tax measures as an instrument in an SVAR analysis. They find that the federal corporate tax cuts increase investment, do not influence or even lower private consumption, and have no impact on employment. Chen et al. (2017) argue that the decline in corporate income tax rate is one of the essential drivers of the recent rise in corporate savings. Their suggested mechanism is that decline in the corporate tax rate decreases cost of capital and raises the markups. Both of these increase the corporate profits and decrease labor share so that the corporate saving increases. Shuai and Chmura (2013) document for US states that the employment growth significantly increases with lower corporate tax rates. Djankov et al. (2010) use a cross-country empirical analysis to show the negative impact of effective corporate tax on aggregate investment, FDI, and entrepreneurial activity. Also, their results indicate that corporate taxes are correlated with investment in the manufacturing sector, whereas they are not in the services sector. Arulampalam et al. (2012) and Fuest et al. (2018) show that corporate tax leads to a decline in wages for European firms and German firms.

Backus et al. (2008) examine the sources of capital-output heterogeneity across countries, indicating that the corporate tax negatively affects it. Liu and Williams (2019) empirically demonstrate that corporate tax cuts affect less capital-intensive states more than the other states in the US. Their model indicates that the reallocation of resources between states and between sectors plays a vital role in explaining this result. Suárez Serrato and Zidar (2016) examine the welfare impacts of corporate tax on workers, landowners, and firms. Their mechanism is that a tax cut decreases the tax liability and raises the cost of capital for local firms. Lower tax rates attract firms, which boots the local labor demand and encourages migration to that state. Thus, the location decisions of both firms and workers determine the impact of tax cuts. Atanassov and Liu (2020) state that corporate innovation rises sharply with a corporate tax cut. Akcigit et al. (2022) empirically investigate the effect of corporate taxes on innovation at both firm and state levels. They show that corporate income taxes negatively affect the number of patents, whereas the number of citations of patents does not significantly change. Akcigit and Ates (2019) analyze the underlying factors behind the changes in US business dynamism. Their investigation implies that the corporate taxation does not have a powerful impact on the changes in business dynamism.

The research work by Cloyne et al. (2022) is the closest to ours as they investigate the effects of corporate tax cut on technology and rationalize their findings by using a model with endogenous innovation. Like them, we f find find a tax cut stimulates innovation but in contrast to the authors, we how that technology improvements are concentrated toward traded industries. In addition we show that innovation does not increase in continental European countries. While we corroborate the muted response of labor for English speaking/Scandinavian countries, we find a strong and significant response of labor in continental European countries. In this regard, our identification allows us to identify key international differences in the effects of corporate tax cuts.

2 Data and methodology

We document the empirical evidence on the effects of corporate taxation on traded and non-traded sectors for 11 OECD countries by estimating a panel structural VAR model with annual data. We initially explain the data and identification of tax shock and then present the empirical results.

2.1 Data

We use the top statutory corporate income tax rates which taken from Bachas et al. (2022)[1]. They combine data from Vegh and Vuletin (2015), Egger et al. (2019), Tax Foundation and country-specific sources. They use the lower rate if there are conflicting estimates. The largest period available between 1973 and 2017 [2] for eleven OECD countries: Australia (AUS), Austria (AUT), Belgium (BEL), France (FRA), Germany (DEU), Finland (FIN), United Kingdom (GBR), Japan(JPN), Luxembourg (LUX), Sweden (SWE), and United

[1]https://globaltaxation.world

[2]Australia and the United Kingdom, the corporate income tax rate data is unavailable before 1973

States (USA)[3]
The primary sources for sectoral data are the OECD and EU KLEMS databases. Our dataset includes thirteen industries that are allocated as tradable or non-tradable as in Bertinelli et al. (2022). Table 1 displays the classification of industries into tradable and non-tradable sectors.

First, we set up the analysis for all economies at the aggregate level. Second, we empirically explore the responses of broad sectors following a rise in corporate tax rate by 1 percentage point. We used the following macroeconomic variables in the VAR estimations.

Table 1: Summary of Sector Classification

Sector	ISIC-rev.4 Classification Industry	Code
Tradable (T)	Agriculture, Forestry and Fishing	A
	Mining and Quarrying	B
	Total Manufacturing	C
	Transport and Storage	H
	Information and Communication	J
	Financial and Insurance Activities	K
Non Tradable (N)	Electricity, Gas and Water Supply	D-E
	Construction	F
	Wholesale and Retail Trade, Repair of Motor Vehicles and Motorcycles	G
	Accomodation and Food Service Activities	I
	Real Estate Activities	L
	Professional, Scientific, Technical Administrative and Support Service Activities	M-N
	Community Social and Personal Services	O-U

Source: EU KLEMS (2017) and OECD (2017)

All quantity variables are divided by the working-age population (15-64 years old) taken from OECD ALFS Database. All variables are from Bertinelli et al. (2022). The definition of aggregate and sectoral variables are as follows (mnemonics are in parentheses):

- Aggregate variables: real GDP (Y) is the sum of traded and non-traded value added at constant prices. Total hours worked (L) is the sum of traded and non-traded hours worked.

- Sectoral quantities: traded value added at constant prices (Y_H), non-traded value added at constant prices (Y_N). Sectoral value added are constructed by adding value added for all sub-industries k in sector $j = T, N$

[3]Spain, Norway, and Italy are dropped because they do not have a declining corporate income tax rate trend. We drop Canada, Netherlands, Greece, Ireland, Korea, Portugal, and Denmark because of the lack of data before 1980s.

- Sectoral hours worked: traded hours worked (L_T), non-traded hours worked (L_N) which correspond to hours worked by persons engaged in sector j. Sectoral hours worked are constructed by adding hours worked for all sub-industries k in sector $j = T, N$

- Sectoral hours worked share (L_j/L), is the ratio of hours worked in sector j to total hours worked for $j = T, N$.

- Labor income share (LIS) is constructed as the ratio of labor compensation which is the total of compensation of employees and compensation of self-employed in sector $j = T, N$ to value added at current prices of that sector.

- Sectoral value added share is the ratio of value added at constant prices in sector j to GDP at constant prices, i.e., Y_j/Y for $j = T, N$

- Capital utilization adjusted total factor productivity, TFP, is constructed as the Solow residual from constant-price domestic currency series of GDP, labor income share and capital stock. The time-varying capital utilization series is constructed using the methodology in Imbs (1999).

- R&D capital stock is the net capital stock in constant prices in Research and Development. R&D investment is gross fixed capital formation in constant prices in Research and Development.

- Sectoral nominal wage is calculated as the ratio of the labor compensation in sector $j = T, N$ to total hours worked by persons engaged in that sector. Nominal wages are divided to foreign price (W_j/P_j^* for $j = T, N$) which is exogenous geometric weighted sum of the traded value added deflator of the ten trade partners of the corresponding country i, the weight being equal to the share of imports from the trade partner k.

- Relative price of non-tradables, P_N/P_T. Normalizing base year price indices $\bar{P}_j$ to 1, the relative price of non-tradables is constructed as the ratio of the non-traded value added deflator to the traded value added deflator. The sectoral value added deflator P_j for sector j = T;N is calculated by dividing value added at current prices (VA) by value added at constant prices in sector j.

- Terms of trade, $TOT_{it} = P_T/P_T^*$ is computed as the ratio of the traded value added deflator of the home country i, P_{it}^T , to the geometric average of the traded value added deflator of the twenty trade partners of the corresponding country i, the weight being equal to the share of imports from the trade partner. We use the traded value added deflator to approximate foreign prices as it corresponds to a value-added concept.

2.2 Methodology

2.2.1 VAR identification of corporate tax shock

The novelty of our analysis is to identify a permanent shock to corporate income tax rate. The major problem in identifying shocks to corporate income taxation is to ensure that these shocks are exogenous to economic activity. Thus, it prevents us from using country-level corporate income tax rates as there is a clear endogeneity issue. The existing literature has so far concentrated on the narrative measure of tax rates to identify the exogenous changes in tax rates (Romer and Romer (2010), Mertens and Ravn (2013) and Cloyne (2013)). However, the narrative measure of tax changes is not available most of the countries and in corporate tax rate level and as emphasized by Perotti (2012), decision-markers could assert that they focus on public debt while they are interested in mitigating the effects of a recession which in turn will bias the estimated effect (from the narrative approach) of a tax cut on value added downward.

The identification of a permanent shock to corporate taxation lies on the observation that tax competition has given rise to a downward trend in the corporate tax rates in most of OECD countries. In addition to generating a gradual decline in corporate taxation, the willingness to attract capital implies that country-level tax rates share a common component which is specific to coporate taxation, i.e., the entity which is taxed can cross the borders. Tax competition refers to the process whereby countries compete with each other to attract businesses by offering lower tax rates and other favorable tax conditions. This competition can have a permanent effect on corporate income tax rates because businesses will continue to seek out countries with lower tax rates, leading to a downward pressure on tax rates in other countries. As businesses move to countries with lower tax rates, governments in other countries may be forced to lower their own tax rates in order to remain competitive. This creates a cycle of tax competition, as each country continually lowers its tax rates in an effort to attract businesses.Persson and Tabellini (1992) show theoretically that in the Nash equilibrium, tax competition leads to a reduction in taxes of the mobile factor (capital) more than the immobile factor (labor). Devereux et al. (2008) empirically show that corporate tax cuts are to attract multinational and more profitable firms.

International tax competition begins only when capital can move freely across countries. In this part of the study, we examine the relationship between financial openness and the statutory corporate tax rate. We utilized the dataset from Lane and Milesi-Ferretti (2018) to calculate financial openness index as the ratio of assets plus liabilities to GDP.

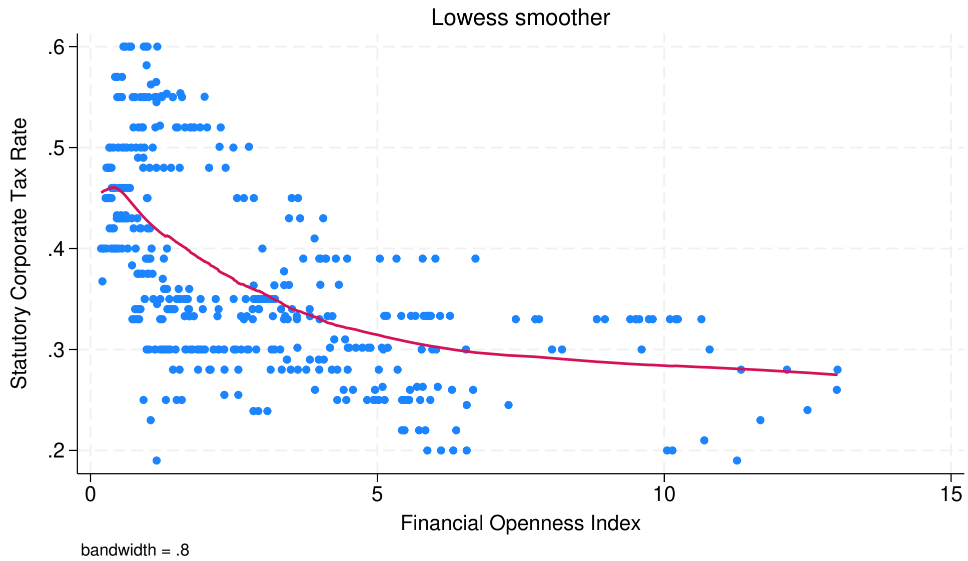


Figure 1: Fitting scatter plot for the relationship between financial openness index and statutory corporate tax rate

As expected, Figure 1 indicates a negative correlation between financial openness and the corporate tax rate, meaning that countries with more open capital markets tend to have lower corporate tax rates.

To test further the relationship between capital openness and corporate tax rate, we used the idea of Devereux et al. (2003). In situations where capital can easily move across borders, the decision to invest in a particular country, denoted as i hinges on that country's corporate tax rates compared to those of other countries j where $j \neq i$. In this analysis, we used more sophisticated capital openness index which is the Chinn-Ito index (KAOPEN) [4].

The approach cited above is estimated with a regression of the form

$$\tau_{it} = \beta_1 \kappa_{it} + \beta_2 \kappa_{it} \tau_{it}^{int} + \beta_3 X_{it} \tag{1}$$

where τ_{it} is statutory corporate income tax rate for country i at year t, κ_{it}[5] is the capital openness index and X is for the control variables such as country size, public debt to GDP ratio and unemployment rate. Tax levels of countries are positively related to taxes of other countries and especially close countries like neighbors (Davies and Voget, 2009)). To capture more accurately the degree of international competition faced by each country i, we construct an international tax rate $k = 1...10$ of each country i by considering the trade intensity between the home country and its trade partner within ten countries as a weight:

$$\tau_{it}^{int} = \sum_{k \neq i}^{10} \alpha_{IM}^{i,k} \tau_{kt} \tag{2}$$

[4]KAOPEN represents the first principal component derived from the initial variables related to regulatory restrictions on current or capital account movements, the presence of multiple exchange rates, and mandates concerning the submission of export earnings. For further information, please consult Chinn and Ito (2008).

[5]The Chinn-Ito index normalized to range between zero and one

where $\alpha_{IM}^{i,k}$ is the trade share of home countries i with the partner country k and τ_{kt} is the statutory corporate income tax rate of the partner country. The most important feature of this tax measure is that it does not contain the countries own corporate tax rate. This makes international tax rate exogenous to the country's economic conditions.

Table 2: Regression results

	(1)	(2)	(3)	(4)
	τ_{it}	τ_{it}	τ_{it}	τ_{it}
κ_{it}	-0.298***	-0.459***	-0.382***	-0.414***
	(-6.22)	(-10.86)	(-5.48)	(-9.80)
$\tau_{it}^{int} * \kappa_{it}$		0.815***	0.637***	
		(6.83)	(4.55)	
Log of Population			-0.00971	
			(-0.08)	
Log of public debt to GDP			-0.00628	
			(-0.31)	
Unemployment Rate			-0.170	
			(-0.42)	
$\hat{\tau}_{it}^{int} * \kappa_{it}$				0.678***
				(7.79)
_cons	0.636***	0.500***	0.617	0.498***
	(15.23)	(14.04)	(0.51)	(17.34)
Country FE	Yes	Yes	Yes	Yes
adj. R^2	0.476	0.714	0.676	0.667

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2 displays the results of the regression specified in 1. The results clearly demonstrate a negative correlation between the capital openness index and the statutory corporate income tax rate. In Column 2, it is evident that the coefficient of the interaction term is negative, indicating that the negative effect of capital openness only persists when the international tax rate is sufficiently low. Therefore, countries tend to reduce their corporate tax rates when the tax rates of other countries are low. The results remain in column 3 when we add control dummies.

In specifications 2, international tax rates is determined by country corporate tax rate, and so the regressor τ_{it}^{int} is endogenous. We deal with this using an instrumental variable approach. As a first stage, we first regress τ_{it}^{int} on its lag and on X_{it}, and derive predicted values of τ_{it}^{int} which shown in the table as $\hat{\tau}_{it}^{int}$. The result of this IV regression is shown in Column (4) of the Table 2. The sign and the size of the coefficients are consistent with baseline regression.

Figure 2 displays the country corporate tax rate, import share weighted tax rate and cross country average tax rate for eleven OECD countries. It is apparent in the figure that there is a common stochastic trend for eleven countries but we allow for the cross-sectional dependence to show that there is a standard shock that influences eleven countries. According to Westerlund (2007) panel cointegration tests, we can conclude that there is a cointegration relationship between log country income corporate tax rate and log of import share weighted tax rate. (Details of unit root and cointegration tests are in the Appendix.)

Figure 2: The evolution of statutory country corporate income tax rates, cross country average tax rates and import share weighted corporate tax rates for 11 OECD Countries

Our identification of a permanent shock to the corporate tax rate lies on the assumption that the permanent decline in corporate income tax rates are not related to the economic condition of the country. This can be done in order to attract new businesses to the country or to keep existing businesses from leaving. Overall, our empirical evidence supports the idea that the primary driver of a permanent decline in corporate tax rates is the competitive environment between countries rather than the economic situation of a specific country. Thus, in the VAR analysis we will investigate a shock to the international corporate tax rate τ_{it}^{int}.

3 VAR evidence

As in Gali (1999), we base our identification method on the fact that the variable of interest, i.e. international corporate tax rate, has a unit root. Since the international tax rate variables are I(1), we can have permanent shock.

Although the SVAR estimations might be subject to small sample biases, a panel data with 11 countries can compensate the limited time horizon. Also, the confidence bounds are tighter in the panel SVAR estimations than when estimations are run at a country level. Our panel VAR estimation includes the international tax rate and the aggregate and sectoral level macroeconomic variables. Tax rates are in variation and macroeconomic variables enter the VAR model in growth rate and we impose long-run restrictions, i.e., we assume that the matrix of long-run effects is lower triangular.

To explore empirically the dynamic effects of a shock to the international corporate tax rate, we consider a vector of n observables

$$\hat{y}_{it} = [\Delta\tau_{it}^{int}, \hat{V}_{it}] \tag{3}$$

where $\Delta\tau_{it}^{int}$ consists of the first difference of the international tax rates in equations (26). $\hat{V}_{it}^{1}$ denote the growth rate of macroeconomic variables.
Let us consider the following reduced form of the VAR(p) model:

$$C(L)\hat{y}_{it} = u_{it} \tag{4}$$

where $C(L)$ is a p-order lag polynomial and u_{it} is a vector of reduced-form innovations with a variance-covariance matrix given by $E[u_{it}u_{it}'] = \sum_u$. We estimate the reduced form of the VAR model by panel OLS regression with country fixed effects which are omitted in (3) or expositional convenience. The vector of orthogonal structural shocks $\epsilon_{it} = [\epsilon_{it}^{\tau}, \epsilon_{it}^{V}]$ is related to the vector of reduced form residuals u_{it} through: $u_{it} = A_0\epsilon_{it}$ which implies $\sum_A = A_0A_0'$ with A_0 the matrix that describes the instantaneous effects of structural shocks on observable. The linear mapping between the reduced-form innovations and structural shocks leads to the structural moving average representation of the VAR model:

$$\hat{y}_{it} = B(L)A_0^{-1}A_0u_{it} \tag{5}$$

where $B(L) = C(L)^{-1}$. To identify shocks to the productivity differential, ϵ_{it}^{Z}, we use the restriction that the unit root in the international tax rate originates exclusively from corporate tax shocks caused by cross country convergence. Long-run restrictions are implemented through restrictions on $A(L) = B(L)A_0^{-1}$ which implies that the upper triangular elements of the long-run cumulative matrix $A(1) = B(1)A_0^{-1}$ must be zero. When we estimate the reduced form VAR using OLS, structural shocks can be restored with $\epsilon_{it} = A(1)B(1)u_{it}$ where the matrix $A(1)$ is computed as the Cholesky decomposition of $B(1)\sum B(1)'$.

We estimate the reduced form of the VAR model by panel OLS regression with country fixed effects. VAR model includes the international corporate tax rate τ_{it} a vector of aggregate and sectoral variables such as value added at constant prices ${Y^s}_{it}$, hours worked ${L^s}_{it}$, capital utilization adjusted ${TFP^s}_{it}$ for $s = T, N$. Our vector of endogenous variables are as follows:

- Aggreagate economy: $\hat{y}_{it} = [\Delta\tau_{it}, \hat{Y}_{it}, \hat{L}_{it}, T\hat{F}P_{it}]$
- Sectoral level: $\hat{y}_{it} = [\Delta\tau_{it}, \hat{Y^s}_{it}, \hat{L^s}_{it}]$ for $s = T, N$
- Capital utilization adjusted TFP: $\hat{y}_{it} = [\Delta\tau_{it}, T\hat{F}P^T{}_{it}, T\hat{F}P^N{}_{it}]$
- Sectoral composition and labor allocation: $\hat{y}_{it} = [\Delta\tau_{it}, Y_{it}^T\hat{/}Y_{it}, L_{it}^T\hat{/}L_{it}]$
- Labor income share: $\hat{y}_{it} = [\Delta\tau_{it}, LI\hat{S}T_{it}, LI\hat{S}N_{it}]$
- R&D capital stock and investment: $\hat{y}_{it} = [\Delta\tau_{it}, \hat{K^s}_{it}, T\hat{F}P^s{}_{it}]$ for $s = T, N$ where K is for R&D capital stock. $[\Delta\tau_{it}, \hat{I^T}_{it}, \hat{I^N}_{it}]$ where I is for R&D investment.
- Wage rigidity: $\hat{y}_{it} = [\Delta\tau_{it}, \frac{\hat{W_{it}^H}}{P_{it}^{*H}}, \frac{\hat{W_{it}^N}}{P_{it}^{*H}}]$

All variables except international tax rate enter the VAR model in growth rate (denoted by a hat). In line with the current practice (e.g. Beetsma and Giuliodori, 2011, and Corsetti et al., 2012), we use lag length 2 in baseline panel SVAR estimations. We apply unit normalization for the impulse response results. Firstly, we run the estimation for international tax rate and country corporate tax rate. In the second step, we run the estimation for international tax rates and macroeconomic variables. We normalize the impulse response functions of the second step with the estimations in the first step. Thus, we have the impulse responses that demonstrate the response of variables of a shock to the international tax rate, which leads to a 1 percentage point (PPt) cut in the country's corporate tax rate. Additionally, we re scale the response of value added and hours worked in traded and non-traded sectors by the sample average of sectoral value added to GDP and sectoral labor compensation share. Thus, the interpretation of sectoral value added and hours worked is in percentage points of aggregate GDP and total hours worked, respectively.

3.1 Aggregate effects of corporate tax shocks and international differences

In this section, we present the panel SVAR estimation results. The impulse response function (IRF) point estimates are centered at 90% and 68% confidence intervals with 10000 replications in Monte Carlo simulations. Figure 3 displays the impulse response results for value-added and hours worked to a corporate tax cut for eleven countries. The first graph shows the country's corporate tax rate response to a permanent shock to import share weighted tax rate. The shock is normalized to a 1 percentage point decline. The 1 percentage point cut in the corporate income tax rate generates a significant 1.01% rise in output per capita and 0.64% increase in hours worked both in the short and long run for eleven countries. The utilization-adjusted TFP does not increase significantly.

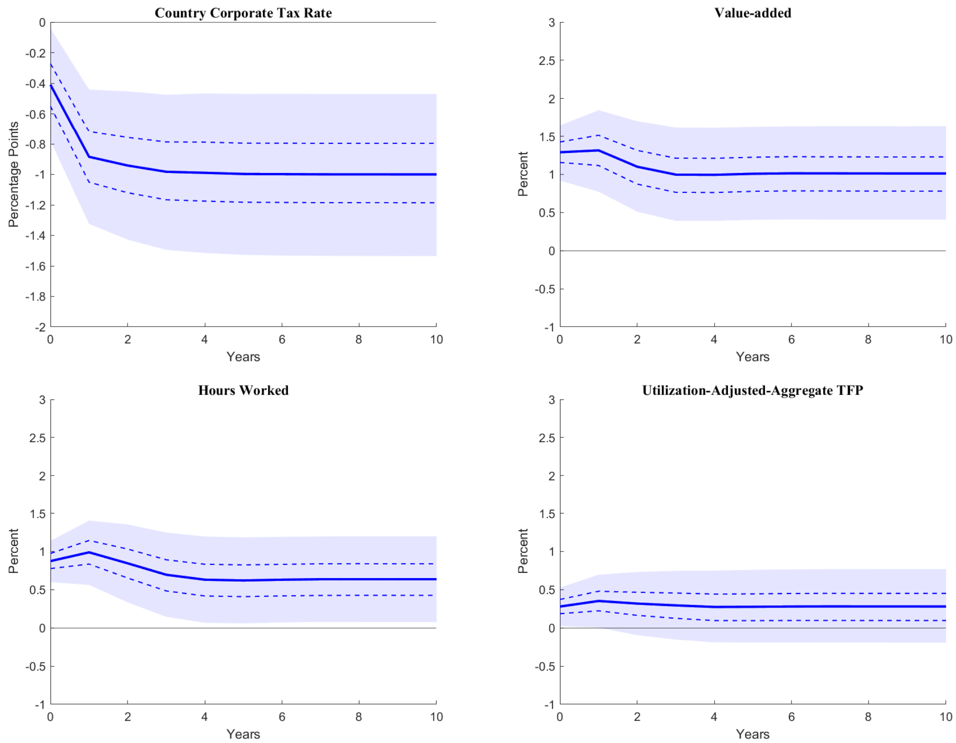


Figure 3: Aggregate Effects of Corporate Tax Shocks

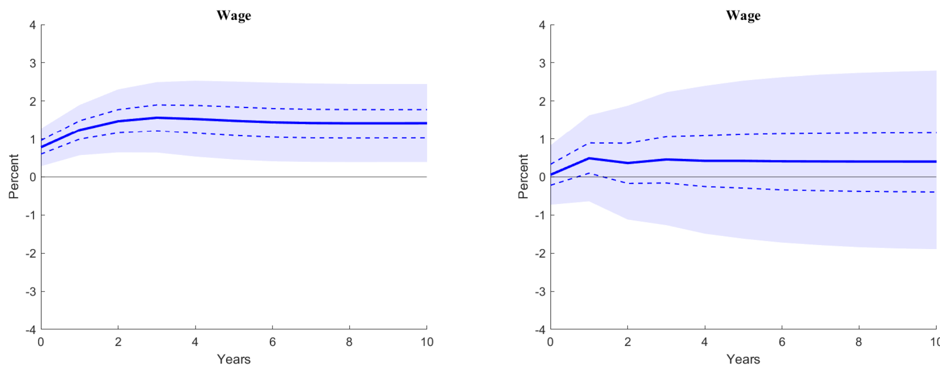
Notes: Exogenous cut of import share weighted corporate tax rate that leads to an 1 percentage point cut in corporate tax rate. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. Shaded areas and dashed lines indicate the 90 percent and 68 percent confidence bounds , respectively and obtained by bootstrap sampling. Sample: 11 OECD countries, 1973-2017, annual data.

The results are compatible with Suárez Serrato and Zidar (2016). They present that a 1 percentage point cut in business taxes leads to a rise between 3.35% and 4.07% in establishment growth and between 3.74% and 4.28% rise in population growth over ten years in the US.

Our hypothesis posits that the impact of corporate taxation on utilization-adjusted total factor productivity (TFP) differs significantly among countries. The variation in the innovation-related consequences of a tax reduction can be attributed to disparities in the costs associated with converting research and development (R&D) expenses into innovative ideas. Conversely, differences in the employment effects across nations will be contingent upon the degree of wage rigidity stemming from labor market regulations.

We used a hierarchical cluster tree method which is based on the idea that data points that are more similar to each other should be placed in the same cluster, while those that are less similar should be placed in separate clusters. Details of the clustering are in the Appendix. Since the Continental European countries are much more tightly related to each other, we split the countries into two groups Continental European countries and the other countries (English-speaking, Scandinavian, Japan, and Luxembourg).

Our results show that a fall in corporate income taxation positively influences labor and aggregate value added for the whole sample, but there may be some variation across countries. The potential reason is the differentiation in labor market regulations of these countries, which affects wages and employment.



(a) E.S. and Scand. Countries (b) Continental European Countries

Figure 4: Effects of Corporate Tax Shocks on Aggregate Wages

Notes: Exogenous cut of import share weighted corporate tax rate that leads to an 1 percentage point cut in corporate tax rate. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. Shaded areas and dashed lines indicate the 90 percent and 68 percent confidence bounds , respectively and obtained by bootstrap sampling. Sample: 11 OECD countries, 1973-2017, annual data.

In contrast, the reverse is valid for the first group of countries with more regulated labor markets. Hence, we set up a panel SVAR estimation to understand the mechanism behind the differences via wage rigidity between the two groups in terms of hours worked. The IRF results for real wages are in Figure 4. A permanent negative shock to the corporate income tax rate influences wage significantly positively in English Speaking and Scandinavian Countries. On the other hand, the effect of corporate tax shock on real wages is zero in Continental European countries. Thus, the wages are rigid in Continental European Countries, whereas they are flexible in English Speaking and Scandinavian Countries after a corporate tax shock.

This section will present the results for panel VAR for two groups. Figure 5 shows the IRF results for English-speaking and Scandinavian countries, Japan, and Luxembourg. The permanent negative shock to corporate income tax causes 1.12% increase in aggregate value-added and 0.65% increase in utilization-adjusted TFP. The response of total hours worked is 0.34%, but it is insignificant in ten years. The utilization-adjusted TFP is positive and significantly affected. Figure 6 shows the IRF results for Continental European countries. The permanent negative shock to corporate tax causes increased aggregate value-added as 0.95% and aggregate hours worked as 1.18% in Continental European countries. At the same time, the utilization-adjusted TFP is not affected by the corporate tax shock. The response of hours worked is positive in Continental Europe, but there is no impact in English Speaking and Scandinavian Countries, Luxembourg, and Japan. More specifically, the second group of countries is known to have more flexible labor markets.

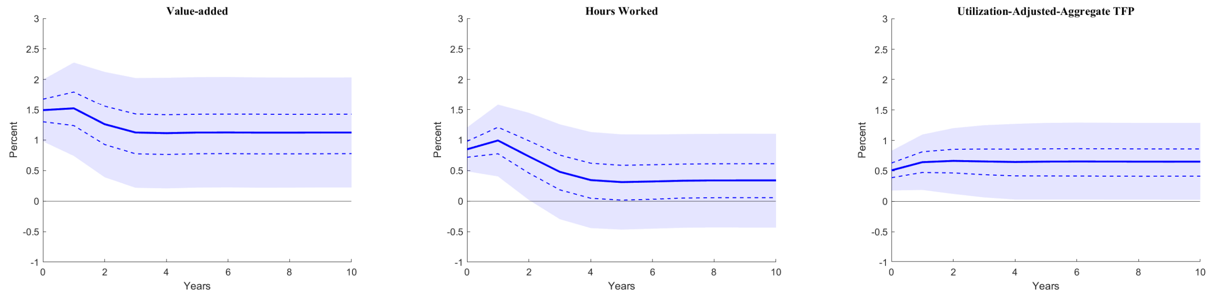


Figure 5: Aggregate Effects of Corporate Tax Shocks in English Speaking and Scandinavian Countries

Notes: Exogenous cut of import share weighted corporate tax rate that leads to an 1 percentage point cut in corporate tax rate. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. Shaded areas and dashed lines indicate the 90 percent and 68 percent confidence bounds , respectively and obtained by bootstrap sampling. Sample: Australia, United Kingdom, and United States, Finland, Sweden, Japan, and Luxembourg, 1973-2017, annual data.

Figure 6 shows the IRF results for Continental European countries. The permanent negative shock to corporate tax causes increased aggregate value-added as 0.95% and aggregate hours worked as 1.18% in Continental European countries. At the same time, the utilization-adjusted TFP is not affected by the corporate tax shock.

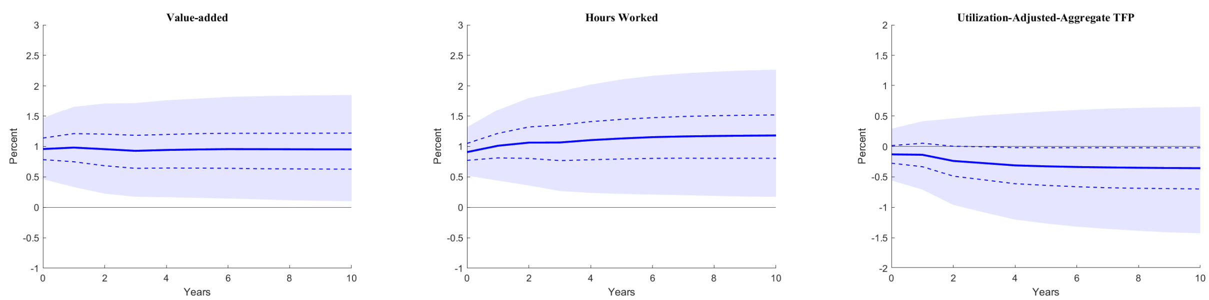


Figure 6: Aggregate Effects of Corporate Tax Shocks in Continental European Countries

Notes: Exogenous cut of import share weighted corporate tax rate that leads to an 1 percentage point cut in corporate tax rate. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. Shaded areas and dashed lines indicate the 90 percent and 68 percent confidence bounds , respectively and obtained by bootstrap sampling. Sample: Austria, Belgium, Germany, France, 1973-2017, annual data.

3.2 Sectoral effects of corporate tax shocks

Figure 7 shows the impulse responses for the traded and non-traded sectors. For both sectors, the response of GDP per capita is positive and significant. Although the traded hours worked increase in the short run, it decreases gradually to zero after ten years. The response of non-traded hours worked is 0.58% and remains constant and significant in the long run. The impact of capital utilization adjusted traded TFP is significantly 1.69% in ten years, whereas it is negative in the non-traded sector. Thus, there is a differentiation between traded and non-traded sectors regarding the response of hours worked and utilization-adjusted TFP. The corporate tax shock impact may differ between sectors because corporate tax may influence sectors' R&D investment differently.

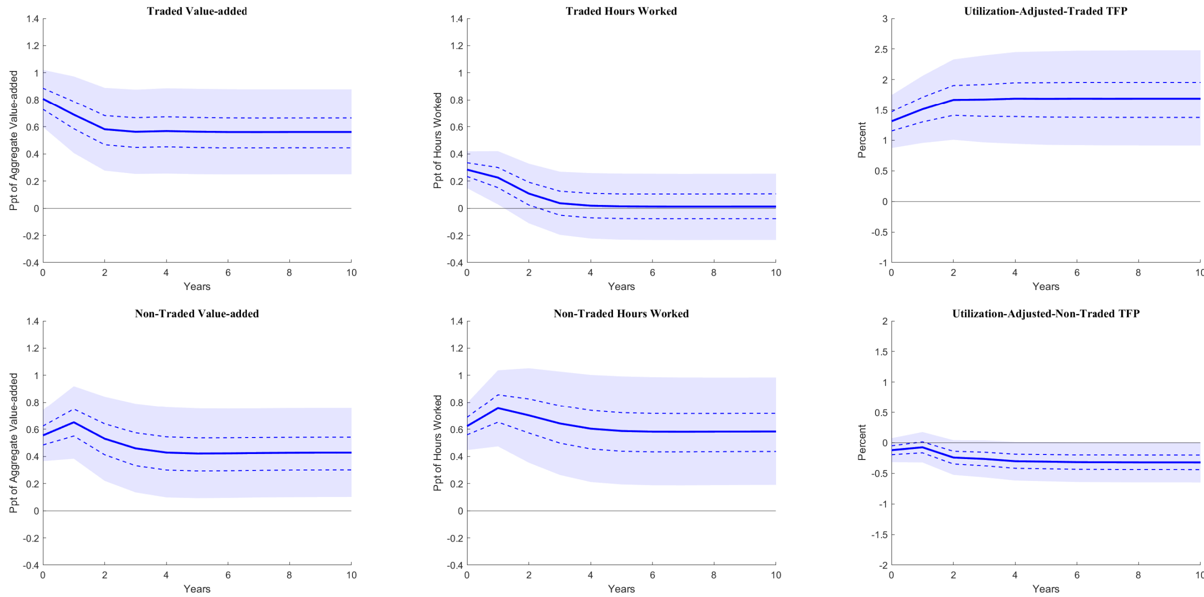


Figure 7: Aggregate Effects of Corporate Tax Shocks

Notes: Exogenous cut of import share weighted corporate tax rate that leads to an 1 percentage point cut in corporate tax rate. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. Shaded areas and dashed lines indicate the 90 percent and 68 percent confidence bounds , respectively and obtained by bootstrap sampling. Sample: 11 OECD countries, 1973-2017, annual data.

Since the exporting firms are more productive than the non-exporting firms, it is natural that a shock to corporate tax affects two sectors asymmetrically. The mechanism behind this distinction may stem from the differences in the R&D intensity of these sectors. Thus, we set up the panel SVAR to analyze the impact of corporate tax shock on R&D capital stock. R&D capital stock data are from the EU KLEM dataset, which is available between 1995 and 2017. The data is unavailable for Australia. Figure 8 displays the IRFs of the R&D capital stock for traded and non-traded sectors for ten countries. A permanent shock to the corporate income tax rate impacts R&D capital stock in the traded sector. However, the impact is almost half of the traded sector in the non-traded sector.

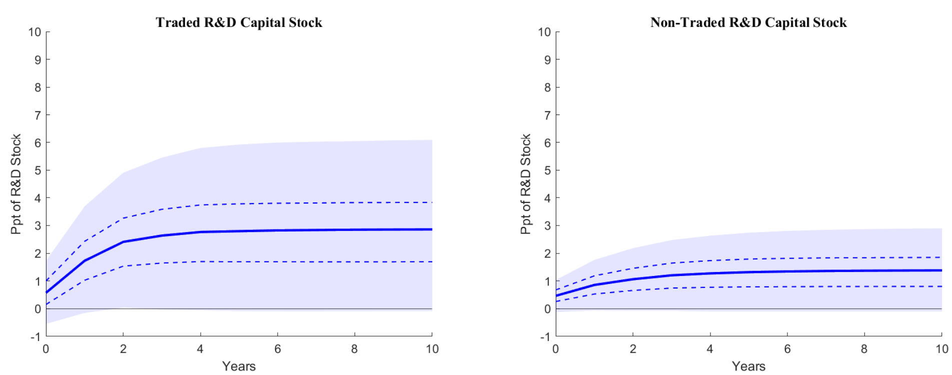


Figure 8: Effects of Corporate Tax Shocks on R&D Capital Stock

Notes: Exogenous cut of import share weighted corporate tax rate that leads to an 1 percentage point cut in corporate tax rate. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. Shaded areas and dashed lines indicate the 90 percent and 68 percent confidence bounds , respectively and obtained by bootstrap sampling. Sample: 10 OECD countries, 1995-2017, annual data.

Intuitively, the decline in corporate tax rate decreases the cost of capital and increases capital investment. The share of intangible capital is higher in the traded sector than in the non-traded sector. Hence, the cost of intangible capital relative to labor decreases more in the traded sector, and firms' demand for traded intangible capital increase more than non-traded intangible capital. The traded sector is affected more than the non-traded sector in accumulating intangible capital; therefore, TFP rises more. Therefore, a permanent tax cut increases R&D investment more in the traded sector than in the non-traded sector. It leads to a higher R&D capital accumulation in the traded sector, influencing the TFP increase. This result is compatible with Akcigit et al. (2022), who empirically investigate the effect of corporate taxes on innovation at both firm and state levels in the US. They show a negative relationship between corporate income taxes and the number of patents.

3.3 International differences in the sectoral effects of corporate tax shock

We assess empirically the impact of a corporate tax cut on technology and labor at a sectoral level by differentiating between English-speaking and Scandinavian countries on one hand and continental European countries on the other. The increase in hours worked is concentrated in the non-traded sector in Continental European Countries. The non-traded hours worked rises 0.8 percentage points of total hours worked significantly, but the increase in traded hours worked is insignificant in ten years.

In contrast, the utilization-adjusted non-traded TFP is negatively affected by the corporate tax cut in English-speaking and Scandinavian countries, Japan, and Luxembourg. The response is 2.74% in utilization-adjusted traded TFP to a one percentage point cut in the corporate tax rate. Thus, the rise in aggregate TFP is concentrated on the rise in traded TFP. Non-traded sector's value added is positively influenced, but it is insignificant for the other group in ten years. The response of hours worked is insignificant in the long run.

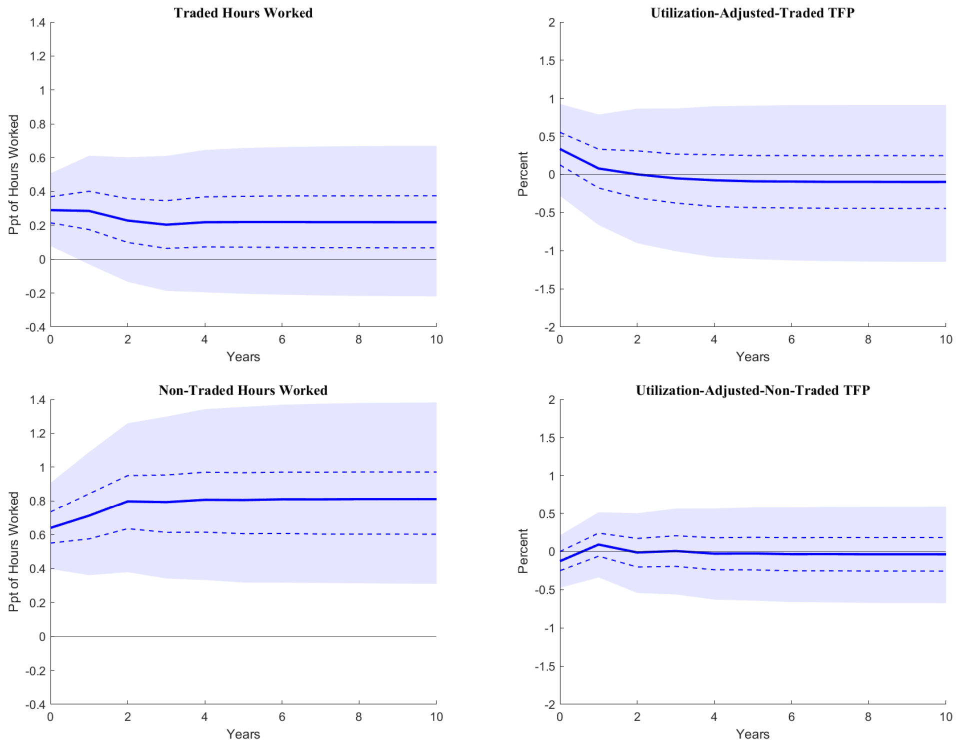


Figure 9: Continental European Countries

Notes: Exogenous cut of import share weighted corporate tax rate that leads to an 1 percentage point cut in corporate tax rate. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. Shaded areas indicate the 90 percent confidence bounds obtained by bootstrap sampling. Sample: Austria, Belgium, Germany, France, 1973-2017, annual data.

Therefore we can conclude that there is a difference between Continental European countries and English-speaking and Scandinavian countries, Japan and Luxembourg. Continental European countries responded by increasing hours worked to a corporate tax cut and the increase is concentrated in the non-traded sector. However, English-speaking and Scandinavian countries, Japan, and Luxembourg responded by raising utilization adjusted TFP to a permanent negative tax shock in the traded sector and it is concentraded in traded sector. The SVAR results reveal that after a decline in profits' taxation, firms in the non-traded sector significantly use more labor in continental European countries but do not increase innovation defined as utilization-adjusted-total factor productivity. In English-speaking and Scandinavian countries, exporting firms increase innovation, which is captured by the rise in utilization-adjusted-total factor productivity, while not significantly increasing labor.

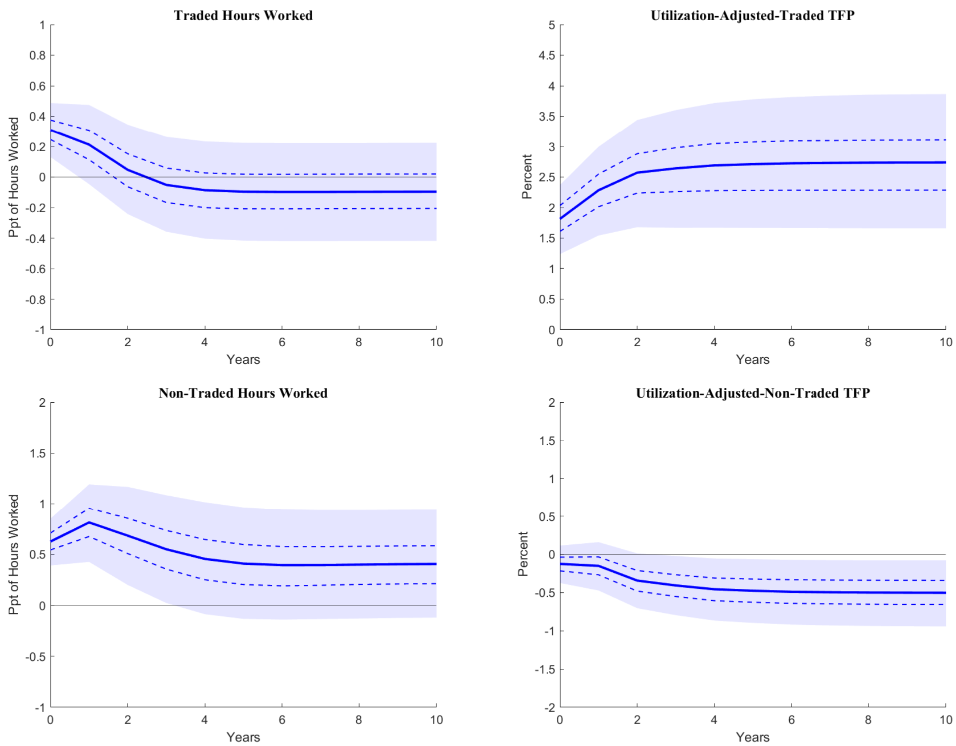
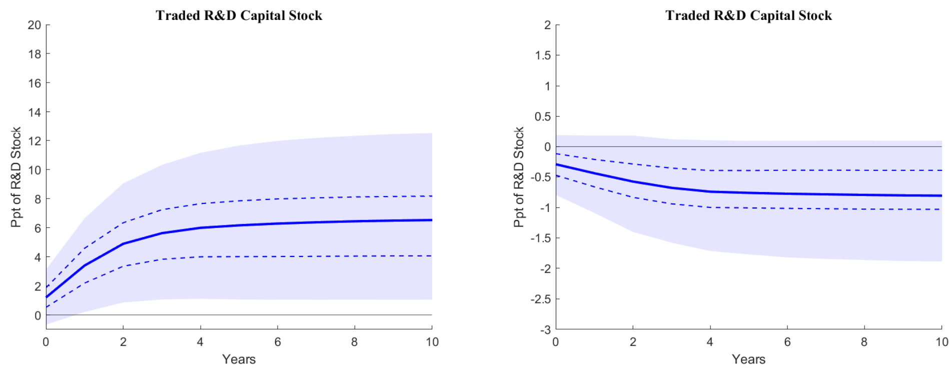


Figure 10: English Speaking and Scandinavian Countries

Notes: Exogenous cut of import share weighted corporate tax rate that leads to an 1 percentage point cut in corporate tax rate. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. Shaded areas indicate the 90 percent confidence bounds obtained by bootstrap sampling. Sample: Australia, United Kingdom, and United States, Finland, Sweden, Japan, and Luxembourg, 1973-2017, annual data.

We estimate the panel SVAR analysis with R&D capital stock for two groups to see the underlying mechanism behind this differentiation. A permanent negative shock to the corporate income tax rate influences traded R&D capital investment significantly positively in English Speaking and Scandinavian Countries. The impact of corporate tax shock on traded sector R&D capital stock is negative in Continental European countries. The R&D capital stock responses can explain the differences between the two groups of countries. The decline in corporate tax rate decreases the cost of capital and increases capital investment in English Speaking and Scandinavian Countries. The corporate tax rate cut does not affect R&D capital investment and accumulation in Continental European Countries. Therefore, the differentiation in TFP responses of two groups of countries stems from the distinction in the R&D capital investment and stock.



(a) ES and Scand. Countries (b) Continental European Countries

Figure 11: Effects of Corporate Tax Shocks on R&D Capital Stock
Notes: Notes: Exogenous cut of import share weighted corporate tax rate that leads to an 1 percentage point cut in corporate tax rate. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. Shaded areas and dashed lines indicate the 90 percent and 68 percent confidence bounds , respectively and obtained by bootstrap sampling. Sample: 11 OECD countries, 1973-2017, annual data.

A corporate income tax rate cut decreases capital costs and raises corporate savings and capital investment. Higher capital accumulation increases the marginal product of labor. If wages are flexible, wages increases, and demand for labor decreases. If wages are rigid, the cost of labor relative to capital is smaller. Thus, the demand increases for labor and employment rises. Adjusting TFP is more costly than labor in Continental European Countries, so the response of these countries is to increase hours worked to a corporate tax shock. On the other hand, other countries have flexible and increasing wages, so the firms respond with R&D capital stock to a corporate tax shock.

3.4 Structural change and labor income share

Starting from the differentiation between traded and non-traded sectors in the previous estimations, we analyze the effect on the output and labor allocations between traded and non-traded sectors to a permanent corporate tax shock. The behaviors of value-added and hours worked allocations between traded and non-traded sectors are opposite. A corporate tax cut positively impacts the share of value-added of the traded sector in total value-added (YT/Y). However, the impact of the share of traded hours worked in total (LT/L) is -0.24 percentage points of hours worked, which is within the 90 percent confidence bounds.

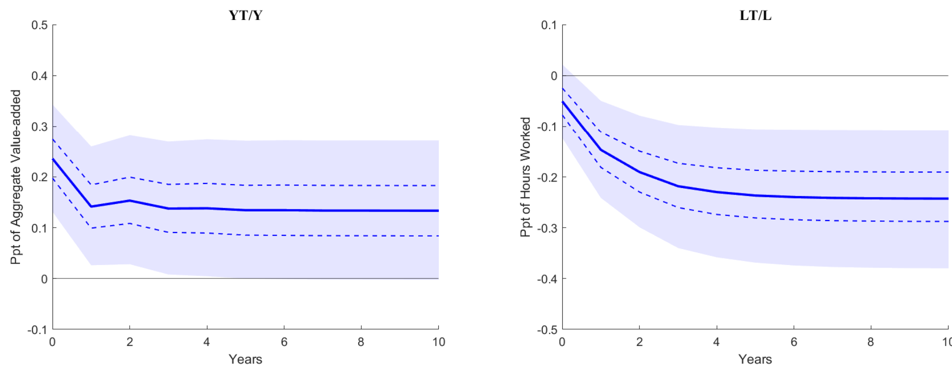


Figure 12: Effects of Corporate Tax Shocks on Structural Change

Notes: Notes: Exogenous cut of import share weighted corporate tax rate that leads to an 1 percentage point cut in corporate tax rate. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. Shaded areas and dashed lines indicate the 90 percent and 68 percent confidence bounds , respectively and obtained by bootstrap sampling. Sample: 11 OECD countries, 1973-2017, annual data.

This result means that corporate tax cut contributes to allocating labor from traded to non-traded sectors. This result can be related to an increased utilization-adjusted TFP in the traded sector. It implies that the trade sector's labor productivity increases more than it does in the non-traded sector, which causes a rise in labor demand in the non-traded sector if traded and non-traded sectors are complements.

We investigate the impact of a corporate tax cut on structural change with the distinction between the two groups of countries. For English Speaking and Scandinavian Countries, a fall in the corporate tax rate produces an increase in value added in traded sector relative to value-added in non-traded sector. As innovation in traded sector increases, it depreciates the terms of trade (PT/PT^{*}) and appreciates the relative price of non-tradables (PN/PT). The reason is that there is an excess supply of home-produced traded goods relative to non-traded goods.

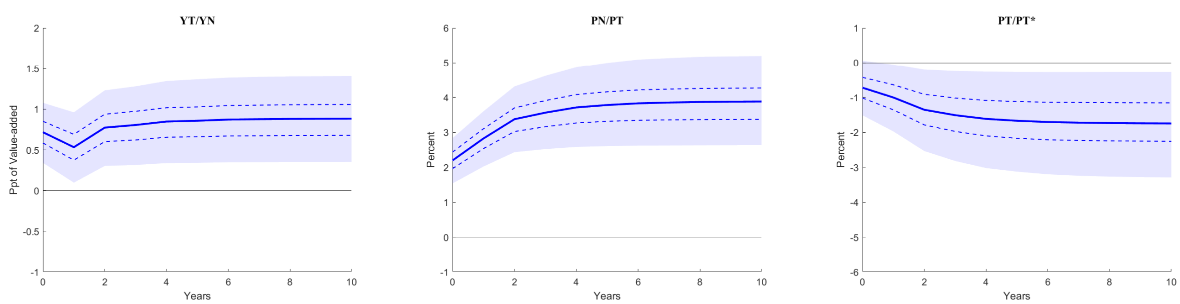


Figure 13: English Speaking and Scandinavian Countries

Notes: Exogenous cut of import share weighted corporate tax rate that leads to an 1 percentage point cut in corporate tax rate. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. Shaded areas and dashed lines indicate the 90 percent and 68 percent confidence bounds , respectively and obtained by bootstrap sampling. Sample: Australia, United Kingdom, and United States, Finland, Sweden, Japan, and Luxembourg, 1973-2017, annual data.

For Continental European Countries, since the labor in non-traded sector increases,the relative price of non-tradables (PN/PT) decreases and the terms of trade (PT/PT^{*}) increases. There is an excess supply of non traded goods relative to traded goods in Continental

European Countries.

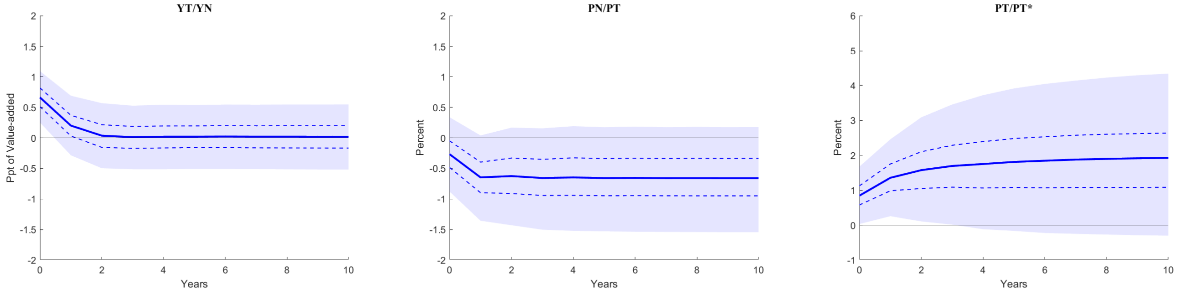


Figure 14: Continental European Countries

Notes: Exogenous cut of import share weighted corporate tax rate that leads to an 1 percentage point cut in corporate tax rate. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. Shaded areas indicate the 90 percent confidence bounds obtained by bootstrap sampling. Sample: Austria, Belgium, Germany, France, 1973-2017, annual data.

The secular decline in labor income share has been a prominent phenomenon observed in many economies over the past few decades. Thus, we want to analyze the impact of a corporate tax shock on labor income share. The labor income share refers to the portion of national income that goes to labor in the form of wages, salaries, and other compensation. Figure 15 shows the response of labor income share to a corporate tax shock in traded and non-traded sectors. One percentage corporate tax cut does not lead to a significant variation in the labor income share in the traded and non-traded sectors. Negative or unresponsive labor income shares contradict the findings by Kaymak and Schott (2022), who claim a positive relationship between corporate tax and labor income share.

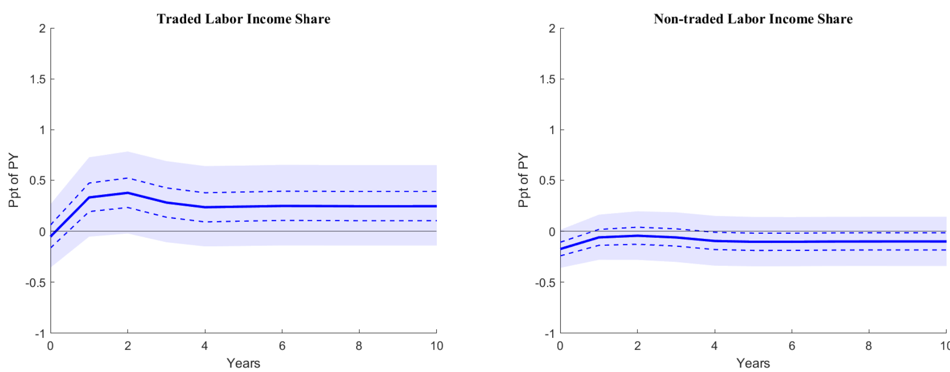


Figure 15: Effects of Corporate Tax Shocks on Labor Income Share

Notes: Notes: Exogenous cut of import share weighted corporate tax rate that leads to an 1 percentage point cut in corporate tax rate. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. Shaded areas and dashed lines indicate the 90 percent and 68 percent confidence bounds , respectively and obtained by bootstrap sampling. Sample: 11 OECD countries, 1973-2017, annual data.

4 Robustness checks

We have conducted several robustness checks detailed in Online Appendix B, w.r.t. the data construction, the measure of technology, and exogeneity of corporate tax shock. We summarize the main results below.

Classification of tradables vs. non-tradables. Our dataset covers eleven industries which are classified as tradables or non tradables. Two sectors display an ambiguity, including "Financial Intermediation" and "Real Estate, Renting and Business Services" which are made up of sub-sectors which display a high heterogeneity in terms of trad- ability. A third industry "Hotels and Restaurants" that we classify as non-tradables has experienced a large increase in tradability over the last fifty years. We perform a sensitivity analysis with respect to the classification for the three aforementioned sectors in Appendix B.1. Treating "Financial Intermediation" as non-tradables or classifying "Hotels and Restaurants" or "Real Estate, Renting and Business Services" as tradables does not affect our main results.

Decomposition of the sectoral effects at a sub-sector level. Our dataset covers eleven industries which are classified as tradables or non-tradables. The traded sector is made up of five industries and the non-traded sector of six industries. In Appendix B.2, we estimate the dynamic effects of a permanent corporate tax cut at a thinner industry level in order to assess whether all industries of the same broad sector behave in the same fashion following a tax cut. We find that all traded industries experience an increase in utilization-adjusted-traded-TFP which rises persistently in Mining, Manufacturing and Finance. With regards to the non-traded industries, we find that the responses of non-traded industries clustered around the X-axis. With regard to labor, all non-traded industries experience a permanent increase in hours worked. We can notice that the rise is persistent in Real Estate, Construction, Wholesale and Retail Trade, Hotels and Restaurants. Hours worked remain muted in all traded industries except for Transport and Communication. The rise in value added is mostly driven by Manufacturing and Transport and Communication while the most of the rise in non-traded value added originates from Construction and Wholesale and Retail Trade.

Alternative measures of technology. In Online Appendix B.3, We replace the measure of utilization adjusted TFP based on the Solow residual adjusted with the capital utilization rate obtained by applying the Imbs method with three alternative measures. First, building on Basu (1996) approach which has the advantage of controlling for unobserved changes in both capital utilization and intensity of worker effort while we control for the intensity in the use of capital only by adapting Imbs (1999) method, we construct time series for utilization-adjusted-TFP at a sectoral level for all countries of our sample. Second, we use time series from Huo et al. (2023) and Basu et al. (2006). Overall, a technology improvement produces similar effects across measures of technology. Importantly, the adjustment of utilization-adjusted-aggregate TFP is very close whether we adjust the Solow residual with the capital utilization rate or with alternative methods.

The number of lags. Erceg et al. (2005), Chari et al. (2008) have shown that persistent non-technology shocks can disturb the identification of permanent technology shocks if they account for a large fraction of output fluctuations. Because the SVAR allows for a limited number of lags, the SVAR model faces some difficulties to disentangle pure technology shocks from other shocks which have long-lasting (or even permanent) effects on labor productivity. De Graeve and Westermark (2013) find that raising the number of lags may be a viable strategy to achieve identification when long-run restrictions are imposed on the VAR model. To check the robustness of our assumption of two lags when estimating the VAR model and identifying a permanent cut in the corporate tax rate by means of long-run restrictions, in Online Appendix B.4, we increase the lags from two to five and find that all of our conclusions stand, in particular a permanent corporate tax cut increases utilization-adjusted TFP only in the traded sector and gives rise to a permanent rise in nnon-traded hours worked.

Exogeneity test. To test the exogeneity of the identified corporate tax shocks, we test whether the shock is correlated with other shocks like demand shocks. In Appendix B.5, we consider three types of shocks: unanticipated temporary changes in taxation, in government spending, and in monetary policy. If our identification is accurate, corporate tax shocks have no correlation with demand shocks or tax shocks. The F-test indicates that none of the variables hold significance in explaining our identified technology shocks.

Comparison with narrative measure: US case. In Appendix B.6, we compare our corporate tax measure for the US with the narrative measure provided by Mertens and Ravn (2013) to provide evidence that our tax measures are also exogenous. We run a SVAR long run restrictions estimation for output consumption and investment by using narrative measure, cross country average tax rate and import share weighted average tax rate. The impulse response functions for GDP per capita and consumption are close narrative measure and import share weighted corporate tax rate.

5 Conclusion

Through the development of a novel identification method for exogenous and permanent cut in corporate taxation, we investigate the dynamic impacts of such changes on labor and innovation, observing substantial variations across countries and sectors. Our identification approach relies on the downward trend of corporate tax rates observed in OECD countries, driven by global competition to attract capital after the removal of capital controls. Analyzing a panel of eleven OECD countries spanning from 1973 to 2017, our structural vector autoregression (SVAR) analysis uncovers that a decrease in taxes on profits leads to concentrated technology advancements in industries involved in international trade, while labor growth primarily originates from non-traded industries.

By dividing our sample of eleven OECD countries into two sub-samples, we empirically establish that continental European countries experience a significant increase in labor, while hours worked remain relatively unchanged in English-speaking and Scandinavian countries. Conversely, lower corporate taxes stimulate innovation among traded firms in English-speaking and Scandinavian countries, as indicated by a permanent improvement in utilization-adjusted total factor productivity. However, innovation levels remain largely unchanged in continental European countries. Supporting these findings, sector-specific time series data on R&D capital stock corroborate our results, demonstrating a significant increase in the stock of ideas only in the traded sector of English-speaking and Scandinavian countries following a permanent tax reduction.

Consistent with the predictions of our model, a corporate tax cut leads to increased labor in countries with sticky wage conditions, while simultaneously fostering innovation in countries where the cost of innovation is relatively low. The empirical results of this paper open new doors for future studies. The information produced in this study can be effectively combined with dynamic macroeconomic models, which investigate the impacts of corporate tax shock. It would be a crucial contribution to the literature.

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A More Empirical Results

In this section, we present the empirical results that support our tax shock identification and country split. Our identification of international corporate tax shocks is based on the assumption that time series for tax rate is I(1). Appendix A.1 shows panel unit tests for all variables considered in the empirical analysis. Also, In Appendix A.2, we present the results for the cross-sectional dependence to show that there is a standard shock that influences eleven countries. In Appendix A.3, there is the details of hierarchical cluster tree method to split the sample into two groups of countries.

A.1 Panel Unit Root Tests

When estimating alternative VAR specifications, all variables enter in growth rates except tax rates. In order to support our assumption of I(1) variables, we ran panel unit root tests displayed in Table 3. We consider five panel unit root tests among the most commonly used in the literature: Levin et al. (2002) (hereafter LLC), Breitung (2001), Im et al. (2003) (hereafter IPS), and Hadri (2000). All tests, with the exception of Hadri (2000), consider the null hypothesis of a unit root against the alternative that some members of the panel are stationary. Additionally, they are designed for cross sectionally independent panels. LLC and IPS are based on the use of the Augmented Dickey-Fuller test (ADF hereafter) to each individual series of the form $\Delta x_{i,t} = \alpha_i + \rho_i x_{i,t-1} + \sum_{j=1}^{q_i} \theta_{i,j} \Delta x_{i,t-j} + \varepsilon_{i,t}$, where $\varepsilon_{i,t}$ are assumed to be i.i.d. (the lag length q_i is permitted to vary across individual members of the panel). Under the homogenous alternative the coefficient ρ_i in LLC is required to be identical across all units ($\rho_i = \rho$, $\forall i$). IPS relax this assumption and allow for ρ_i to be individual specific under the alternative hypothesis. MW propose a Fisher type test based on the p-values from individual unit root statistics (ADF for instance). Like IPS, MW allow for heterogeneity of the autoregressive root ρ_i under the alternative. We also apply the pooled panel unit root test developed by Breitung (2001) which does not require bias correction factors when individual specific trends are included in the ADF type regression. This is achieved by an appropriate variable transformation. As a sensitivity analysis, we also employ the test developed by Hadri (2000) which proposes a panel extension of the Kwiatkowski et al. (1992) test of the null that the time series for each cross section is stationary against the alternative of a unit root in the panel data. Breitung' and Hadri's tests, like LLC's test, are pooled tests against the homogenous alternative.[6]

As noted above, IPS test allows for heterogeneity of the autoregressive root, accordingly, we will focus intensively on these tests when testing for unit roots. Across all variables the null hypothesis of a unit root against the alternative of trend stationarity cannot be rejected at conventional significance levels, suggesting that the set of variables of interest are integrated of order one. When considering the Hadri's test for which the null hypothesis implies stationary against the alternative of a unit root in the panel data, we reach the same conclusion and conclude again that all series are nonstationary. Taken together, unit root tests applied to our variables of interest show that non stationarity is pervasive, suggesting that all variables should enter in the VAR models in growth rate.

[6] In all aforementioned tests and for all variables of interest, we allow for country-fixed effects. Appropriate lag length q_i is determined according to the Akaike criterion.

Table 3: Panel Unit Root Tests

	LLC		Breitung		IPS		Hadri	
	Stat.	p-value	Stat.	p-value	Stat.	p-value	Stat.	p-value
τ^c	-0.374	0.354	1.621	0.948	1.810	0.965	115.109	0.000
τ^{int}	-0.234	0.408	4.344	1.000	3.457	1.000	132.449	0.000
Y	-2.940	0.002	5.152	1.000	1.341	0.910	137.498	0.000
Y^T	-2.105	0.018	5.209	1.000	1.886	0.970	134.692	0.000
Y^N	-2.649	0.004	5.355	1.000	1.557	0.940	137.321	0.000
L	0.205	0.581	-0.719	0.236	-0.831	0.203	66.738	0.000
L^T	-3.903	0.000	3.266	0.999	0.639	0.739	133.844	0.000
L^N	2.429	0.992	3.802	1.000	4.488	1.000	118.663	0.000
TFP_{ADJ}	-6.066	0.000	3.774	1.000	-2.042	0.021	131.677	0.000
TFP^T_{ADJ}	-5.287	0.000	3.631	1.000	-0.927	0.177	135.298	0.000
TFP^N_{ADJ}	-3.290	0.001	2.247	0.988	-1.436	0.075	99.252	0.000
G	-2.627	0.004	5.803	1.000	0.961	0.832	133.073	0.000
C	-2.232	0.013	5.832	1.000	1.983	0.976	137.338	0.000
I	-0.242	0.404	3.865	1.000	2.024	0.979	139.024	0.000
P^N/P^T	-2.330	0.010	4.478	1.000	1.405	0.920	132.277	0.000
P^T/P^{T*}	-3.125	0.001	0.383	0.649	-2.527	0.006	79.136	0.000
P^N/P^{T*}	-1.620	0.053	3.297	1.000	1.939	0.974	123.205	0.000
s_L	-1.080	0.140	0.739	0.770	-1.353	0.088	90.021	0.000
s^T_L	0.843	0.800	1.209	0.887	0.170	0.568	90.712	0.000
s^N_L	-1.376	0.084	0.155	0.562	-1.417	0.078	84.638	0.000
T^T/Y^N	-0.057	0.477	2.350	0.991	1.031	0.849	98.278	0.000
Y^T/Y	-0.054	0.479	2.400	0.992	1.015	0.845	98.228	0.000
Y^N/Y	-0.047	0.481	2.271	0.988	1.071	0.858	98.308	0.000
W/P^{T*}	-3.792	0.000	3.136	0.999	-0.079	0.468	126.272	0.000
W^T/W	-1.533	0.063	1.740	0.959	-1.335	0.091	89.347	0.000
W^N/W	-4.398	0.000	1.701	0.956	-3.830	0.000	73.046	0.000
K^T_{RD}	-2.039	0.021	0.080	0.532	1.309	0.905	38.722	0.000
K^N_{RD}	-4.708	0.000	0.770	0.779	1.044	0.852	74.347	0.000

Notes: For LLC, Breitung and IPS, the null of a unit root is not rejected if p-value $\geq$ 0.05 at a 5% significance level. For Hadri, the null of stationarity is rejected if p-value $\leq$ 0.05 at a 5% significance level. All tests two lags in the Augmented Dickey-Fuller regressions.

A.2 Cross-sectional Dependence

We check for the cross-sectional dependence to show that there is a standard shock that influences eleven countries. We test for weak cross-sectional dependence by applying the Pesaran (2015) test. It rejects the null hypothesis that errors are weakly cross-sectional dependent with CD = 40.82 and p-value = 0.000 for the country's corporate tax rate. Rejects the null hypothesis with CD = 48.16 and p-value = 0.000 for import share weighted corporate tax rate. This result implies that both series present cross-sectional dependence. Thus we have to apply unit root and cointegration tests that consider this dependence. Secondly, we test the unit root null hypothesis in panel data. The panel unit root hypothesis cannot be rejected for country-level corporate tax rates, and import share weighted corporate tax rates. Therefore there is a unit root and series are I(1). Since the international tax rate variables are I(1), we can have permanent shock. As the last step, we estimate the cointegration relationship between the two series. We run Westerlund (2007) panel cointegration tests to show the cointegration between a country's corporate tax rate and import share weighted corporate tax rate. Among the four stats of Westerlund (2007), three of them (Gt, Ga, Pa) reject the no cointegration null hypothesis. As Gt and Ga allow for some heterogeneity in the cointegration vector across individuals, we can conclude that there is a cointegration relationship between log country income corporate tax rate and log of import share weighted tax rate.

Table 4: Westerlund ECM panel cointegration tests for country corporate tax rate and import share weighted corporate tax rate

Statistic	Value	Z-value	P-value	Robust P-value
Gt	-2.265	-1.800	0.036	0.01
Ga	-8.678	-0.936	0.175	0.01
Pt	-6.096	-1.302	0.097	0.1
Pa	-6.040	-1.352	0.088	0.09

Note: The null hypothesis of no cointegration is rejected if the p-value is below 0.05 (0.1) at 5% (10%) significance level 1 lag, 1 lead and a constant.

A.3 Country Categorization

The literature categorizes the OECD countries into three groups Continental European countries, Scandinavian (Nordic) countries, and English-speaking (Anglo-Saxon) countries (Faggio and Nickell, 2007, Storm and Naastepad, 2009). Continental European countries Scandinavian countries have comparatively regulated and coordinated labor markets, but Scandinavian countries have more centralized bargaining power and a more generous unemployment benefit system. English-speaking countries have an unregulated and uncoordinated labor market relative to the other OECD countries.

Thus, to split the sample into two groups of countries, we use the share of permanent contracts, the union density, the bargaining coverage which are negatively correlated with wage flexibility and ranks countries by using a hierarchical tree We used these variables as the columns. All variables are average of 1973 and 2017.

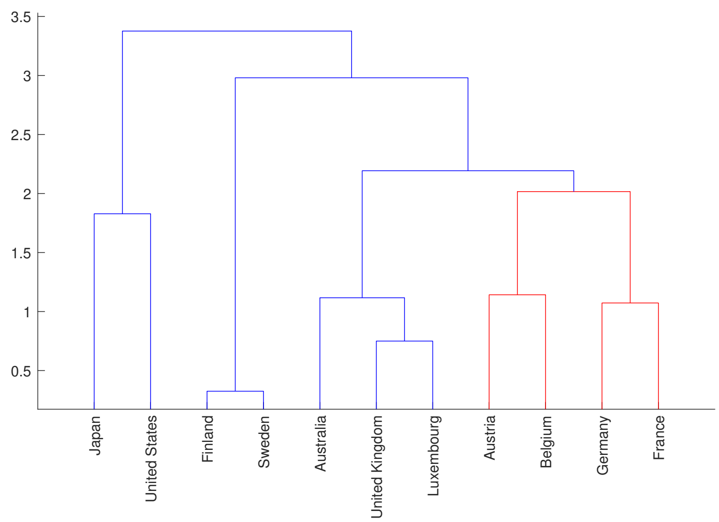


Figure 16: Clustering of countries based on labor market structure

We used a hierarchical cluster tree method which is based on the idea that data points that are more similar to each other should be placed in the same cluster, while those that are less similar should be placed in separate clusters. In a hierarchical cluster tree, the height of the link represents the distance between the two clusters that include two countries. Our clustering provides valuable insights us with categorization of countries. Continental European countries (Austria, Belgium, Germany, and France) are closest to each other than the other countries. Scandinavian countries (Finland and Sweden) are most relative to each other.

The labor market regulations of Scandinavian countries tend to be less rigid than those of continental European countries. In Scandinavian countries, labor market regulations are often designed to promote employment and job creation. For example, these countries tend to have more flexible hiring and firing practices, as well as lower minimum wages than continental European countries (Svalund, 2013).

B Robustness Checks

In this section, we conduct some robustness checks.

Due to data availability, we use annual data for eleven 1-digit ISIC-rev.3 industries that we classify as tradables or non-tradables. At this level of disaggregation, the classification is somewhat ambiguous because some broad sectors are made-up of heterogenous sub-industries, a fraction being tradables and the remaining industries being non-tradables. Since we consider a sample of 11 OECD countries and a period running from 1973 to 2017, the classification of some sectors may vary across time and countries. Industries such as 'Transport and Communication', 'Finance Intermediation' classified as tradables, 'Hotels and Restaurants' classified as non-tradables display intermediate levels of tradedness which may vary considerably across countries but also across time. Subsection B.1 deals with this issue and conducts a robustness check to investigate the sensitivity of our empirical results to the classification of industries as tradables or non-tradables.

Our dataset covers eleven industries which are classified as tradables or non tradables. The traded sector is made up of five industries and the non-traded sector of six industries. In subsection B.2, we conduct our empirical analysis at a more disaggregate level. The objective is twofold. First, we investigate whether all industries classified as tradables or non-tradables behave homogeneously or heterogeneously. Second, we explore empirically which industry drives the responses of broad sectors following a 1 percentage point cut in corporate tax.

B.1 Classification of Industries as Tradables vs. Non-Tradables

This section explores the robustness of our findings to the classification of the eleven 1-digit ISIC-rev.3 industries as tradables or non tradables.

Following De Gregorio et al. (1994), we define the tradability of an industry by constructing its openness to international trade given by the ratio of total trade (imports + exports) to gross output. Data for trade and output are provided by the World Input-Output Databases. Table 5 gives the openness ratio (averaged over 1995-2014) for each industry in all countries of our sample. Unsurprisingly, "Agriculture, Hunting, Forestry and Fishing", "Mining and Quarrying", "Total Manufacturing" and "Transport, Storage and Communication" exhibit high openness ratios (0.54 in average if "Mining and Quarrying", due to its relatively low weight in GDP, is not considered). These four sectors are consequently classified as tradables. At the opposite, "Electricity, Gas and Water Supply", "Construction", "Wholesale and Retail Trade" and "Community Social and Personal Services" are considered as non tradables since the openness ratio in this group of industries is low (0.07 in average). For the three remaining industries "Hotels and Restaurants", "Financial Intermediation", "Real Estate, Renting and Business Services" the results are less clearcut since the average openness ratio amounts to 0.18 which is halfway between the two aforementioned averages. In the benchmark classification, we adopt the standard classification of De Gregorio et al. (1994) by treating "Real Estate, Renting and Business Services" and "Hotels and Restaurants" as non traded industry. Given the dramatic increase in financial openness that OECD countries have experienced since the end of the eighties, we allocate "Financial Intermediation" to the traded sector. This choice is also consistent with the classification of Brainard and Collins (2005) who categorize "Finance and Insurance" as tradable. They use locational Gini coefficients to measure the geographical concentration of different sectors and classify sectors with a Gini coefficient below 0.1 as non-tradable and all others as tradable (the authors classify activities that are traded domestically as potentially tradable internationally).

Table 5: Openness Ratios per Industry: 1995-2014 Averages

	Agri.	Minig	Manuf.	Elect.	Const.	Trade	Hotels	Trans.	Finance	Real Est.	Public
AUS	0.242	0.721	0.643	0.007	0.005	0.025	0.255	0.247	0.054	0.051	0.054
AUT	0.344	2.070	1.152	0.178	0.075	0.135	0.241	0.491	0.302	0.221	0.043
BEL	1.198	13.374	1.414	0.739	0.067	0.186	0.389	0.536	0.265	0.251	0.042
CAN	0.304	0.821	0.966	0.098	0.002	0.030	0.338	0.211	0.169	0.121	0.038
DNK	0.470	0.786	1.329	0.214	0.014	0.092	0.021	0.832	0.138	0.131	0.027
ESP	0.386	4.699	0.680	0.021	0.003	0.044	0.008	0.206	0.130	0.149	0.022
FIN	0.228	2.899	0.796	0.117	0.006	0.094	0.131	0.280	0.153	0.256	0.021
FRA	0.280	3.632	0.815	0.049	0.004	0.048	0.001	0.224	0.068	0.070	0.014
GBR	0.360	0.853	0.958	0.017	0.010	0.024	0.148	0.209	0.233	0.147	0.041
IRL	0.298	1.384	1.127	0.154	0.013	0.652	0.772	0.285	1.014	0.988	0.049
ITA	0.300	4.130	0.603	0.041	0.013	0.087	0.035	0.150	0.095	0.082	0.012
JPN	0.158	3.923	0.293	0.004	0.000	0.067	0.021	0.159	0.034	0.020	0.005
KOR	0.175	18.603	0.507	0.012	0.003	0.213	0.029	0.388	0.071	0.114	0.052
NLD	0.988	1.496	1.259	0.082	0.076	0.106	0.011	0.562	0.245	0.405	0.114
NOR	0.391	0.837	0.995	0.146	0.024	0.097	0.009	0.354	0.146	0.143	0.058
PRT	0.351	2.954	0.880	0.050	0.005	0.067	0.105	0.378	0.125	0.114	0.026
SWE	0.294	2.263	0.969	0.119	0.020	0.163	0.019	0.392	0.274	0.256	0.026
USA	0.207	0.541	0.428	0.012	0.001	0.055	0.003	0.109	0.066	0.052	0.008
OECD	0.388	3.666	0.879	0.114	0.019	0.121	0.141	0.334	0.199	0.198	0.036
H/N	H	H	H	N	N	N	N	H	H	N	N

Notes: the complete designations for each industry are as follows (EU KLEMS codes are given in parentheses). "Agri.": "Agriculture, Hunting, Forestry and Fishing" (AtB), "Minig": "Mining and Quarrying" (C), "Manuf.": "Total Manufacturing" (D), "Elect.": "Electricity, Gas and Water Supply" (E), "Const.": "Construction" (F), "Trade": "Wholesale and Retail Trade" (G), "Hotels": "Hotels and Restaurants" (H), "Trans.": "Transport, Storage and Communication" (I), "Finance": "Financial Intermediation" (J), "Real Est.": "Real Estate, Renting and Business Services" (K), "Public": "Community Social and Personal Services" (LtQ). The openness ratio is the ratio of total trade (imports + exports) to gross output (source: World Input-Output Databases.

We conduct below a sensitivity analysis with respect to the three industries ("Real Estate, Renting and Business Services", "Hotels and Restaurants" and "Financial Intermediation") which display some ambiguity in terms of tradedness to ensure that the benchmark classification does not drive the results. In order to address this issue, we re-estimate the dynamic responses to a government spending shock for the main variables of interest using local projections for different classifications in which one of the three above industries initially marked as tradable (non tradable resp.) is classified as non tradable (tradable resp.), all other industries staying in their original sector. In doing so, the classification of only one industry is altered, allowing us to see if the results are sensitive to the inclusion of a particular industry in the traded or the non traded sector.

As an additional robustness check, we also exclude the industry "Community Social and Personal Services" from the non-tradable industries' set. This robustness analysis is based on the presumption that among the industries provided by the EU KLEMS and STAN databases, this industry is government-dominated. While this exercise is interesting on its own as it allows us to explore the size of the impact of a government spending shock on the business sector, we also purge for the potential and automatic link between non-traded value added and public spending because government purchases (to the extent that the government is the primary purchaser of goods from this industry) account for a significant part of non-traded value added. The baseline and the four alternative classifications considered in this exercise are shown in Table 6. The last line provides the matching between the color line (when displaying IRFs below) and the classification between tradables and non tradables.

Table 6: Robustness check: Classification of Industries as Tradables or Non Tradables

	KLEMS code	Classification				
		Baseline	#1	#2	#3	#4
Agriculture, Hunting, Forestry and Fishing	AtB	T	T	T	T	T
Mining and Quarrying	C	T	T	T	T	T
Total Manufacturing	D	T	T	T	T	T
Electricity, Gas and Water Supply	E	N	N	N	N	N
Construction	F	N	N	N	N	N
Wholesale and Retail Trade	G	N	N	N	N	N
Hotels and Restaurants	H	N	N	N	**T**	N
Transport, Storage and Communication	I	T	T	T	T	T
Financial Intermediation	J	T	**N**	T	T	T
Real Estate, Renting and Business Services	K	N	N	**T**	N	N
Community Social and Personal Services	LtQ	N	N	N	N	**neither T or N**
Color line in Figure 17		black	blue	red	green	light blue

Notes: T stands for the Traded sector and N for the Non traded sector.

Fig. 17 reports the effects of an exogenous decrease in international corporate tax rate that leads to decrease country corporate tax rate by 1% in the long-run on selected variables shown in Fig. 2 in the main text. The green line and the red line show results when 'Hotels and restaurants' and 'Real Estate, Renting and Business Services' are treated as tradables, respectively. The blue line shows results when 'Financial intermediation' is classified as non-tradables. Finally, the light blue line displays results when Public services ('Community Social and Personal Services') is excluded.

In each panel, the shaded area corresponds to the 90% confidence bounds for the baseline. For aggregate variables shown in the first column, including aggregate utilization-adjusted-aggregate-TFP, total hours worked and real GDP, the responses are remarkably similar a cross the baseline and alternative classifications. As shown in the light blue line which displays the response for the market sector only, the response of variables is little sensitive to the inclusion or not of the pubic services. Inspection of the first row reveals that the classification of industries as tradables or non-tradables has an impact on the utilization-adjusted-TFP of tradables relative to non-tradables. In particular, 'Hotels and restaurants' treated as tradables (classification #3 and shown in the green line) mitigates the rise in traded relative to non-traded technology. But the shape of the dynamic adjustment is similar to the benchmark classification. Aggregate TFP is not sensitive to the classification.

The second row of Fig. 17 contrasts the responses of total hours worked, non-traded hours worked, the hours worked share of tradables. The third row of Fig. 17 contrasts the responses of real GDP. Alternative responses are fairly close to those estimated for the baseline classification as they lie within the confidence interval (for the baseline classification) for all the selected horizons.

In conclusion, our main findings hold and remain unsensitive to the classification of one specific industry as tradable or non-tradable. In this regard, the specific treatment of "Hotels and Restaurants", "Real Estate, Renting and Business Services", "Financial Intermediation" or "Community Social and Personal Services" does not drive the results.

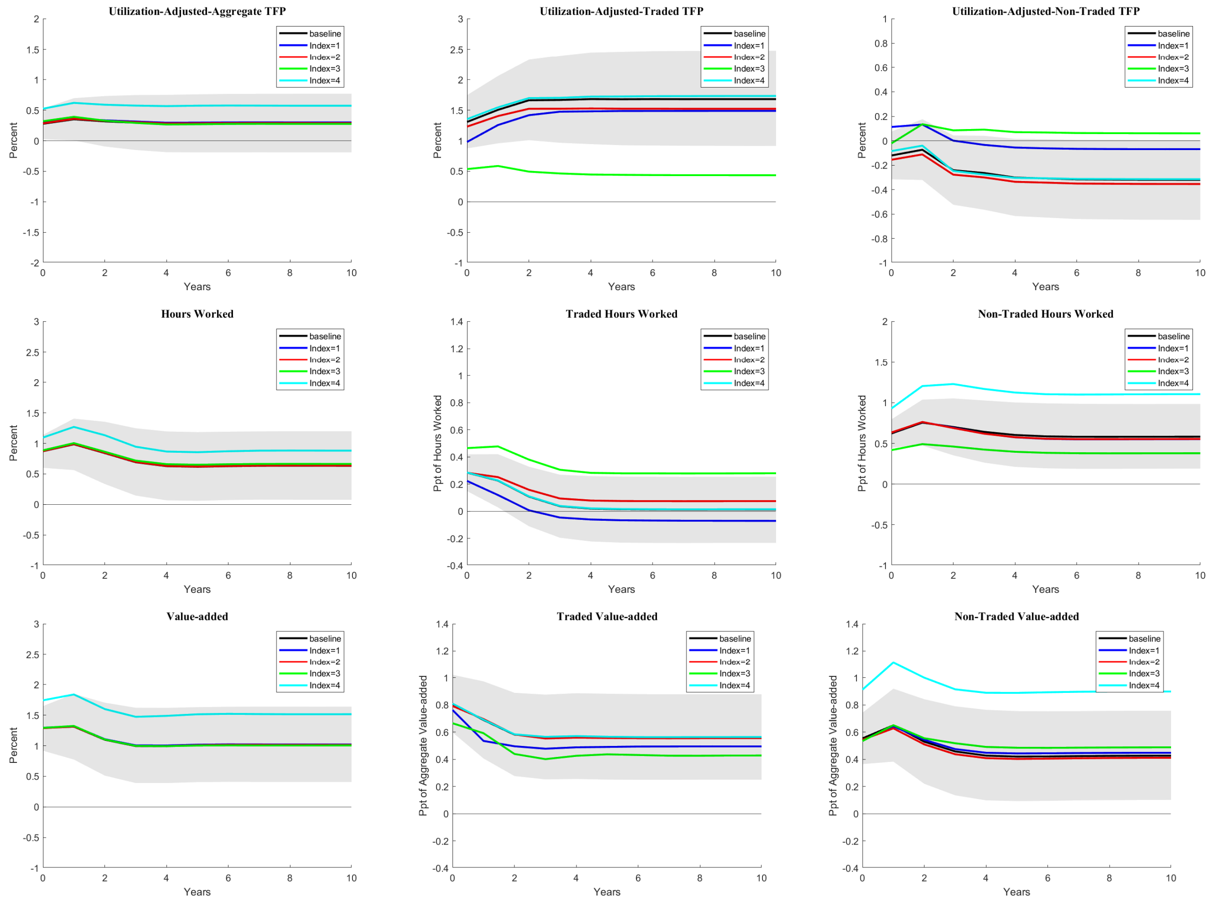


Figure 17: Sectoral Effects of a Corporate Tax Shock: Robustness Check w.r.t. the Classification of Industries as Tradable or Non-Tradable. Notes: The solid black line shows the response of aggregate and sectoral variables to an exogenous decrease in international corporate tax rate that leads to decrease country corporate tax rate by 1% in the long-run. Shaded areas indicate the 90 percent confidence bounds based on Newey-West standard errors. To estimate the dynamic responses to a corporate tax shock, we adopt Gali (1999) method. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. The green line and the red line show results when 'Hotels and restaurants' and 'Real Estate, renting and business services' are treated as tradables, respectively. The blue line shows results when 'Financial intermediation' is classified as non-tradables. Finally, the light blue line displays results when Public services ('Community Social and Personal Services') is excluded. Sample: 11 OECD countries, 1973-2017, annual data.

B.2 How Technology at Industry Level Responds to Aggregate Technology Improvements: A Disaggregated Approach

Empirical analysis at a disaggregate sectoral level. Our dataset covers eleven industries which are classified as tradables or non-tradables. The traded sector is made up of five industries and the non-traded sector of six industries. To conduct a decomposition of the sectoral effects at a sub-sector level, we estimate the responses of sub-sectors to the same identified coporate tax shock by adopting the two-step approach detailed in the main text. More specifically, indexing countries with i, time with t, sectors with j, and sub-sectors with k, we first identify the permanent shock to utilization-adjusted-aggregate-TFP, by estimating a VAR model which includes utilization-adjusted-aggregate, Z_{it}^{A}, real GDP, total hours worked, the real consumption wage (all quantities are divided by the working age population and all variables are in rate of growth) and and next we estimate the dynamic effects by Panel SVAR method.

To express the results in meaningful units, i.e., we multiply the responses of TFP of sub-sector k by the share of industry k in the value added of the broad sector j (at current prices), i.e., $\omega^{Y,k,j} = \frac{P^{k,j}Y^{k,j}}{P^j Y^j}$. We multiply the responses of hours worked within the broad sector j by its labor compensation share, i.e., $\alpha^{L,k,j} = \frac{W^{k,j}L^{k,j}}{W^j L^j}$. We detail below the mapping between the responses of broad sector's variables and responses of variables in sub-sector k of one broad sector j.

The response of $L^{k,j}$ to a technology shock is the percentage deviation of hours worked in sub-sector $k \in j$ relative to initial steady-state: $\ln L_t^{k,j} - \ln L^{k,j} \simeq \frac{dL_t^{k,j}}{L^{k,j}} = \hat{L}_t^{k,H}$ where $L^{k,j}$ is the initial steady-state. We assume that hours worked of the broad sector is an aggregate of sub-sector hours worked which are imperfect substitutes. Therefore, the response of hours worked in the broad sector $\hat{L}_t^j$ is a weighted average of the responses of hours worked $\frac{W^{k,j}L^{k,j}}{W^j L^j}\hat{L}_t^{k,j}$ where $\frac{W^{k,j}L^{k,j}}{W^j L^j}$ is the share of labor compensation of sub-sector k in labor compensation of the broad sector j:

$$\begin{aligned}
\hat{L}_t^j &= \sum_{k \in j} \frac{W^{k,j}L^{k,j}}{W^j L^j}\hat{L}_t^{k,j}, \\
\frac{W^j L^j}{WL}\hat{L}_t^j &= \sum_{k \in j} \frac{W^{k,j}L^{k,j}}{WL}\hat{L}_t^j, \\
\alpha^{L,j}\hat{L}_t^j &= \sum_{k \in j} \alpha^{L,k}\hat{L}_t^{k,j},
\end{aligned} \tag{6}$$

where $\sum_j \sum_k \alpha^{L,k} = 1$. Above equation breaks down the response of hours worked in broad sector j into the responses of hours worked in sub-sectors $k \in j$ weighted by their labor compensation share $\alpha^{L,k} = \frac{W^{k,j}L^{k,j}}{W^j L^j}$ averaged over 1973-2017. In multiplying $\hat{L}_t^{k,j}$ by $\alpha^{L,k}$, we express the response of hours worked in sub-sector $k \in j$ in percentage point of hours worked in the broad sector $j = H, N$.

The response of TFP in the broad sector j is a weighted average of responses $\text{TFP}_t^{k,j}$ of TFP in sub-sector $k \in j$ where the weight collapses to the value added share of sub-sector k:

$$\begin{aligned}
\text{TFP}_t^{k,j} &= \sum_{k \in j} \frac{P^{k,j}Y^{k,j}}{P^j Y^j}\hat{\text{TFP}}_t^{k,j}, \\
\text{TFP}_t^j &= \sum_{k \in j} \frac{P^{k,j}Y^{k,j}}{P^j Y^j}\hat{\text{TFP}}_t^{k,j}, \\
\text{TFP}_t^j &= \sum_{k \in j} \omega^{Y,k,j}\hat{\text{TFP}}_t^{k,j},
\end{aligned} \tag{7}$$

where $\omega^{Y,k,j} = \frac{P^{k,j}Y^{k,j}}{P^j Y^j}$ averaged over 1973-2017 is the value added share at current prices of sub-sector $k \in j$ which collapses (at the initial steady-state) to the value added share at constant prices as prices at the base year are prices at the initial steady-state. Note that $\sum_k \sum_{k \in j} \omega^{Y,k,j} = 1$. In multiplying the response of value added at constant prices in sub-sector $k \in j$ by its value added share $\omega^{Y,k,j}$, we express the response of value added at constant prices in sub-sector $k \in j$ in percentage point of GDP.

The first column of Fig. 18 shows responses of TFP and hours worked of sub-sectors classified in the traded sector and the non-traded sector to a permanent cut in corporate tax rate in the long-run. When we consider an aggregate technology shock, all industries behave as the broad sector as they all experience a permanent technology improvement, except 'Transp.' shown in the green line for which the rise in TFP vanishes in the long-run. More interestingly, the rise in traded TFP is driven by technology improvement in 'Manufacturing' because this sector accounts for the greatest value added share of the traded sector and also experiences significant increases in TFP. With regard to non-traded industries, 'Real Estate, Renting, and Business Services' drives the rise in non-traded hours worked followed by "Construction" and 'Wholesale and Retail Trade'. Hours worked doesn't increase for 'Community Social and Personal Services' (i.e., the public sector which also includes health and education services).

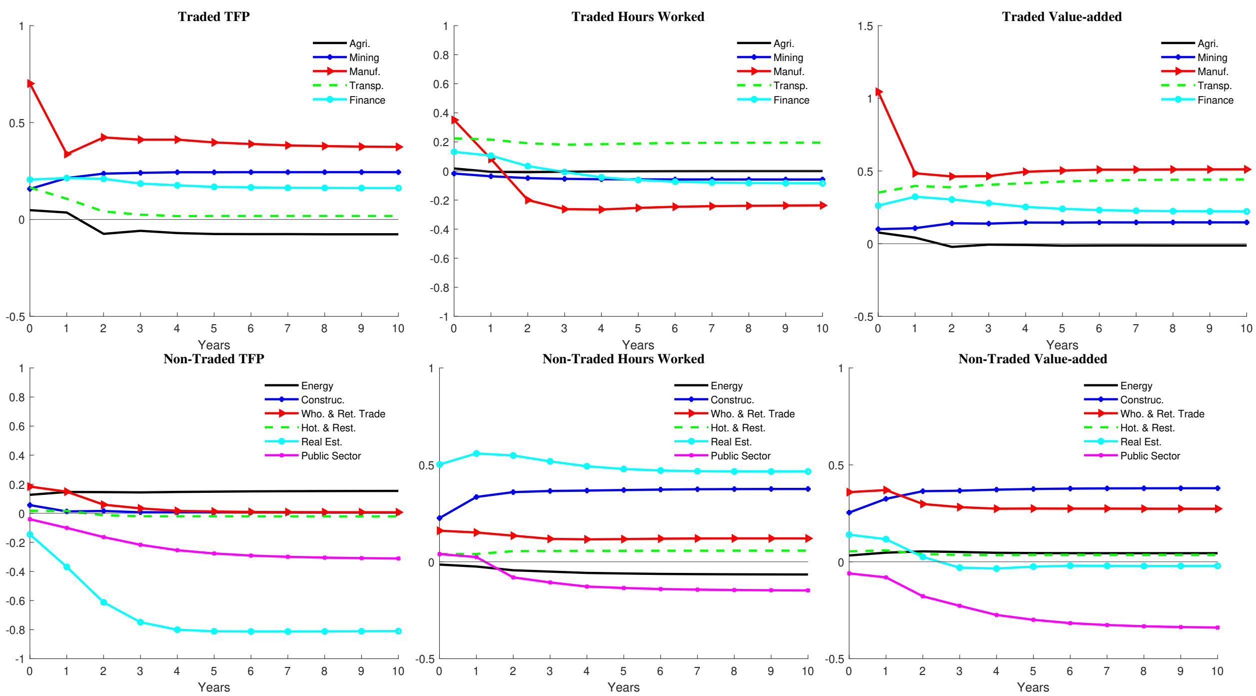


Figure 18: Effects Corporate Tax Shocks on Eleven Sub-Sectors Notes: Because the traded and non-traded sector are made up of industries, we conduct a decomposition of the sectoral effects at a sub-sector level following a an exogenous decrease in the corporrate tax rate by 1% in the long-run. Shaded areas indicate the 90 percent confidence bounds based on Newey-West standard errors. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. To express the results in meaningful units, i.e., total hours worked units, we multiply the responses of hours worked sub-sector k by its labor compensation share (in the traded sector of traded industries or in the non-traded sector for non-traded industries), i.e., $\frac{W^{k,j}L^{j,j}}{W^j L^j}$. The first column shows traded and non-traded industries' responses to aggregate, symmetric and asymmetric technology shocks across sectors. For tradable industries: the black line shows results for 'Agriculture', the blue line for 'Mining and Quarrying', the red line for 'Manufacturing', the green line for 'Transport and Communication', and the light blue line for 'Financial Intermediation'. The second/fourth columns show results for sub-sectors classified in the non-traded sector. For non-tradable industries: the black line shows results for 'Electricity, Gas and Water Supply', the blue line for 'Construction', the red line for 'Wholesale and Retail Trade', the green line for 'Hotels and Restaurants', the cyan line for "Real Estate, Renting and Business Services" and the purple line is for 'Community Social and Personal Services' Sample: 11 OECD countries, 11 industries, 1973-2017, annual data.

B.3 Different Measures of Technology

In this section, we construct a robustness check with respect to the measure of utilization-adjusted TFP. We replace the measure of utilization adjusted TFP based on the Solow residual adjusted with the capital utilization rate obtained by applying the Imbs method with three alternative measures: i) Solow residual adjusted with the utilization rate from Basu (1996), ii) utilization-adjusted TFP from Levchenko et al. 2022, iii) utilization-adjusted TFP from Basu, Kimball and Fernald (2006).

we adopt Basu's [1996] approach which has the advantage of controlling for unobserved changes in both capital utilization and intensity of work effort while we control for the intensity in the use of capital only by adapting Imbs (1999) method. Basu's [1996] approach is based on the ingenious idea that intermediate inputs do not have an extra effort or intensity dimension and thus variations in the use of intermediate inputs relative to measured capital and labor are an index of unmeasured capital and labor input. When adjusting the Solow residual of sector j = H, N with time series for the sectoral capacity utilization rate, we find that technology improves significantly in the traded sector but re- mains unchanged in the non-traded sector following a shock to Git. We do not detect any significant differences between our own measure of technological change and that based on Basu's [1996]. Our measure based on Imbs (1999) is preferred as it is consistent with our modelling strategy where we adjust sectoral TFP with the capital utilization rate.

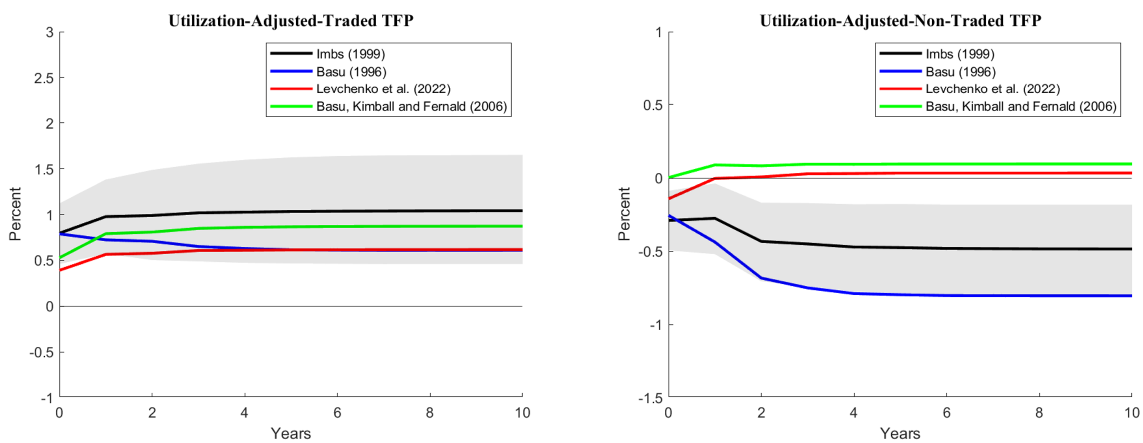


Figure 19: Effects Corporate Tax Shocks on Different Technology Measures<u>Notes</u>: We replace the measure of utilization adjusted TFP based on the Solow residual adjusted with the capital utilization rate obtained by applying the Imbs method with three alternative measures. Black line shows the Imbs, 1999, the blue line is for Basu (1996)), the red line is for Huo et al. (2023), and the green line is for Basu et al. (2006).The period is 1973-2007 (for some countries it is less). We dropped Luxembourg since the data is not available for Huo et al. (2023) and Basu et al. (2006)

B.4 The Number of Lags

The SVAR critique argues that the number of lags in estimating a SVAR is too short to identify consistently a permanent shock to technology. A similar critique could be addressed to the identification of a shock to corporate taxation. The lag truncation bias implies that the identification of a tax shocks could be contaminated by persistent country-specific shocks.

To check the robustness of our results, we increase the number of lags from 2 to 5. For each variable, we compare the IRF of 2 lags with the three other IRFS by considering our initial confidence interval.

Erceg et al. (2005) find that a four-variable SVAR with four lags (as the authors use quarterly data) performs well in recovering the true responses from DGP. More specifically, the SVAR predicts correctly the sign and the pattern of responses but some empirical IRFs are biased as the SVAR tends to understate the rise in labor productivity and real GDP. The source of bias, called the lag-truncation bias arises because the VAR allows for a limited number of lags which provides an approximation of the true dynamics implied by the model which considers an infinite number of lags. Erceg et al. (2005) find that the truncation bias appears negligible for each variable considered by the authors. Thus a short-ordered VAR provides a goods approximation of the true dynamics. In the baseline VAR model, we consider 2 lags. Because Chari et al. (2008) find that increasing the number of lags implies that empirical IRF is a good approximation of theoretical IRF, as a robustness check, we increase the number of lags from 2 to 5 to estimate all VAR models. De Graeve and Westermark (2013) perform Monte Carlo experiments and find that raising the number of lags may be a viable strategy to reduce the severity of the problem. We document below that the results are robust with respect to using a smaller number of lags.

We re-estimate the VAR model of the main text and generate impulse response functions by increasing the number of lags. Note that the SVAR critique focuses on the identification of technology shocks and thus only the number of lags in the VAR model should affect estimation of the response of hours worked.

The baseline VAR model which allows for two lags as we use annual data is displayed by the black line. Whilst in the blue line, we allow for three lags; in the red line, we allow for four lags; in the green line, we allow for five lags. Overall, all responses lie within the 90% confidence bounds of the original VAR model. We may notice some quantitative differences. First, as we increase the number of lags, the rise in the relative productivity and value added of tradables is amplified in the long-run but they mostly stay in the confidence interval. Importantly, the aggregate variables and non traded sector variables remain little sensitive to the increase in the number of lags.

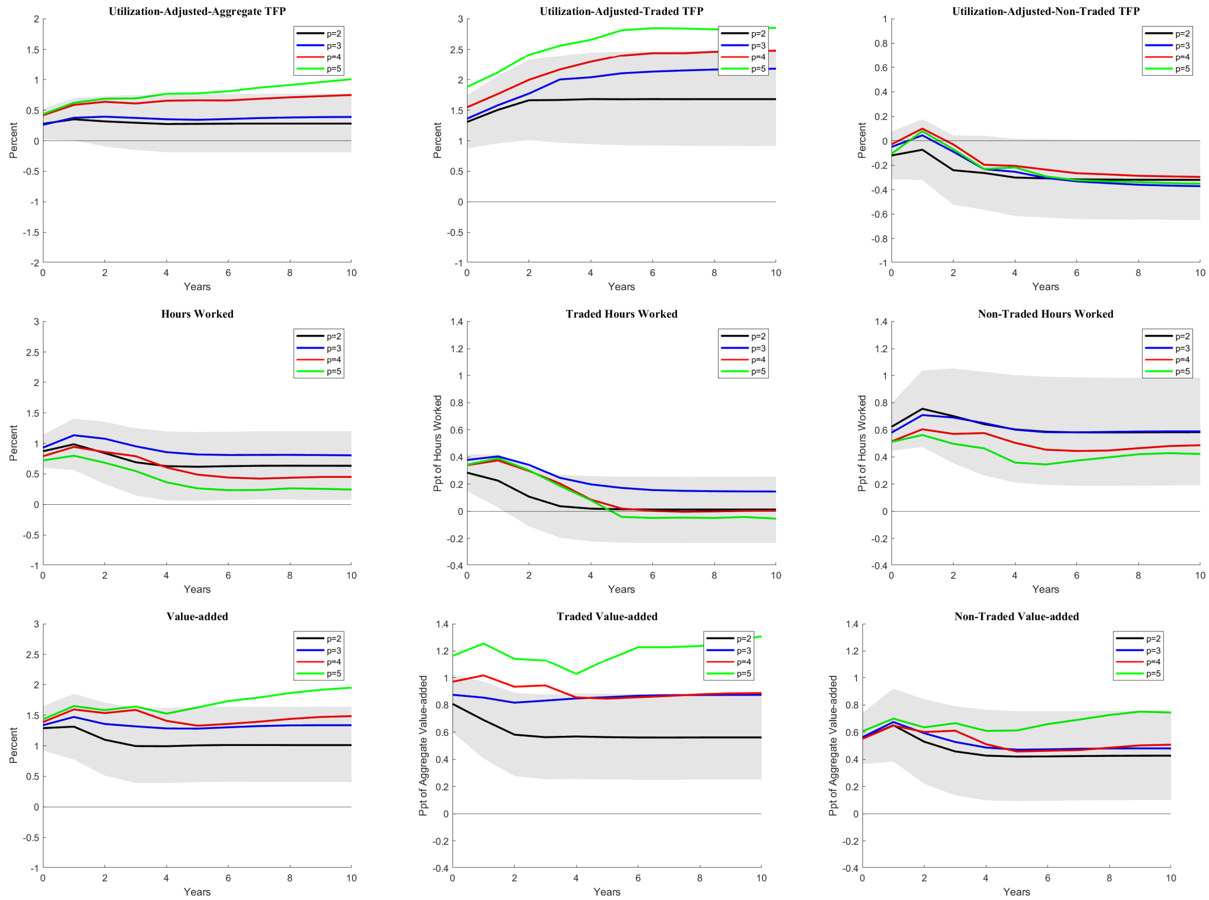


Figure 20: Labor Market Effects of a Corporate Tax Shock: Robustness Check w.r.t. Number of Lags. Notes: The solid blue line shows the response of aggregate and sectoral variables to an exogenous decrease in international corporate tax rate that leads to 1% decline in country corporate tax rate in the long-run. Shaded areas indicate the 90 percent confidence bounds based on Newey-West standard errors. Horizontal axes indicate years. Vertical axes measure percentage deviation from trend. The baseline VAR model which allows for two lags is displayed by the black line. Whilst in the blue line we allow for three lags; in the red line, we allow for four lags; in the green line, we allow for five lags. Sample: 11 OECD countries, 1973-2017, annual data.

B.5 Exogeneity Test

To test the exogeneity of the identified corporate tax shocks, we should test whether the shock is correlated with other shocks like demand shocks. We consider three types of shocks: unanticipated temporary changes in taxation, in government spending, and in monetary policy. We follow the methodology of Blanchard and Perotti (2002) to identify government spending shocks, and the methodology of Christiano et al. (2005) to identify monetary policy shocks. To estimate the effects of these shocks, we use a Vector Autoregression (VAR) model that includes various variables such as government consumption, real GDP, total hours worked, the real consumption wage, utilization-adjusted aggregate total factor productivity, and the short-term interest rate. To ensure consistency, we adjust the nominal interest rate by incorporating foreign prices, as foreign goods and services serve as the benchmark in our model. All quantities are divided by the working age population, and all variables, except for the interest rate, are expressed in logarithmic form. The interest rate is represented in its original level. Similar to Blanchard and Perotti (2002), we employ an identification scheme based on the assumption that there are delays in the legislative system, which prevent government spending from responding immediately to changes in output. Consequently, we prioritize the inclusion of government consumption in the model before other variables. This approach follows the standard Cholesky decomposition introduced by Blanchard and Perotti (2002). Following the approach of Christiano et al. (2005), we identify monetary policy shocks as innovations to the federal funds rate, using a recursive ordering. The policy rate is positioned last in the ordering of variables. This ordering reflects the key assumption that the variables do not respond simultaneously to a monetary policy shock.

Source: Government final consumption expenditure (CGV), OECD Economic Outlook Database [2017]. The short-term interest rate based on three-month money market rates taken from OECD Economic Outlook Database. The nominal interest rate defated by the price of foreign goods which is the numeraire in our model and thus we subtract the rate of change of the weighted average of the traded value added defators of trade partners of the country i from the nominal interest rate denoted by ε_{it}^{R}.

In order to analyze shocks related to tax rates (referred to as ε_{it}^{T}), we utilize a VAR model that incorporates several variables. These variables consist of net taxes, which are defined as taxes minus social security benefits paid by the general government (adjusted for inflation using the GDP deflator), real GDP, total hours worked, the real consumption wage. Following the approach of Blanchard and Perotti (2002), we identify shocks to taxation by assuming that changes in net taxes do not respond to the other variables included in the VAR model within the same year.

Similar to the main text, we determine shocks related to corporate taxes by estimating a VAR model that encompasses various variables. These variables include the international corporate tax rate, real GDP, total hours worked, and the real consumption wage. Using annual data in a panel format, we conduct regression analysis to examine the impact of shocks on tax revenue [7], short-term interest rates, and exogenous shocks to government spending. The period is 1973-2017.

$$\varepsilon_{it}^{\tau} = d_i + \varepsilon_{it}^{G} + \varepsilon_{it}^{R} + \varepsilon_{it}^{T} + v_{it} \tag{8}$$

where v_{it} is an i.i.d. error term; country fixed effects are captured by country dummies, d_i. Note that in estimating eq.(8), we add lagged values (we consider four lags) on explanatory variables which allow us to take into account for the persistence of shocks.

Table 7: Identified Permanent Corporate Tax Shock: Exogeneity Test

	Dependent Variable: ε_{it}^{τ}			
Explanatory Variable	ε_{it}^{G}	ε_{it}^{R}	$\varepsilon^{T_{it}}$	collectively
P-value for Exogeneity Test	0.7352	0.0246	0.8014	0.4431

Notes: The exogeneity F-test is based on a regression of the identified international corporate tax shock ε_{it}^{τ} it on fixed effects and current and four lags of government spending shocks (ϵ_{it}^{G}), monetary shocks (ϵ_{it}^{R}) and taxes shocks (ϵ_{it}^{T}). The null hypothesis is that all of the coefficients on explanatory variables are jointly equal to zero. If p-value $\geq$ 0.05 at a 5% significance level, the variables are not significant in explaining the identified corporate tax shock ε_{it}^{τ}.

[7] Germany, Australia, Luxembourg because there are lacks in net taxes data

If our identification is accurate, we would expect to observe that corporate tax shocks have no correlation with demand shocks or tax shocks. The results of panel data estimations are presented in Table 7. To test the null hypothesis that all coefficients on explanatory variables are collectively equal to zero, we examine the p-value. If the p-value is greater than or equal to 0.05 at a 5% significance level, it indicates that the variables are not significant in explaining the identified corporate tax shock ε^{τ}_{it}. The F-test p-value of 0.443 indicates that none of the variables hold significance in explaining our identified technology shocks.

Table 8: Identified Permanent Corporate Tax Shock: Exogeneity Test

Explanatory Variable	Dependent Variable: ε^{τ}_{it}
ε^{G}_{it}	0.47 (.028)
ε^{R}_{it}	0.79 (.039)
$\varepsilon^{T_{it}}$	-0.96 ($-.029$)
P-value for Exogeneity Test	0.4431
Controls (4 lags on the explanatory variable)	yes
Country Fixed Effects	yes
Countries	8
Observations	295

Notes: t-statistics are reported in parentheses. [a], [b] and [c] denote significance at 1%, 5% and 10% levels. The exogeneity F-test is based on a regression of the identified international corporate tax shock ε^{τ}_{it} it on fixed effects and current and four lags of government spending shocks (ϵ^{G}_{it}), monetary shocks (ϵ^{R}_{it}) and taxes shocks (ϵ^{T}_{it}). The null hypothesis is that all of the coefficients on explanatory variables are jointly equal to zero. If p-value ≥ 0.05 at a 5% significance level, the variables are not significant in explaining the identified corporate tax shock ε^{τ}_{it}.

B.6 Comparison with narrative measure: US case

The literature accepts the narrative measure as exogenous identification for tax shocks because it is viewed as one-to-one mapping into the true structural shocks. However, it is only available for the United States for corporate tax rates. Hence, we compare our corporate tax measure for the US with the narrative measure provided by Mertens and Ravn (2013) to provide evidence that our tax measures are also exogenous. Mertens and Ravn (2013) investigate the impact of corporate tax rates by using narrative measure of corporate tax rate for the period between 1950 and 2006 with quarterly data. Their results indicate that a one percentage point cut in the average corporate tax rate increases real GDP per capita by 0.6 percent after one year, raises private sector investment, and has little effect on private consumption in the short run. We run a SVAR long run restrictions estimation for output consumption and investment by using narrative measure, cross country average tax rate and import share weighted average tax rate. Figure 21 presents the estimation results.

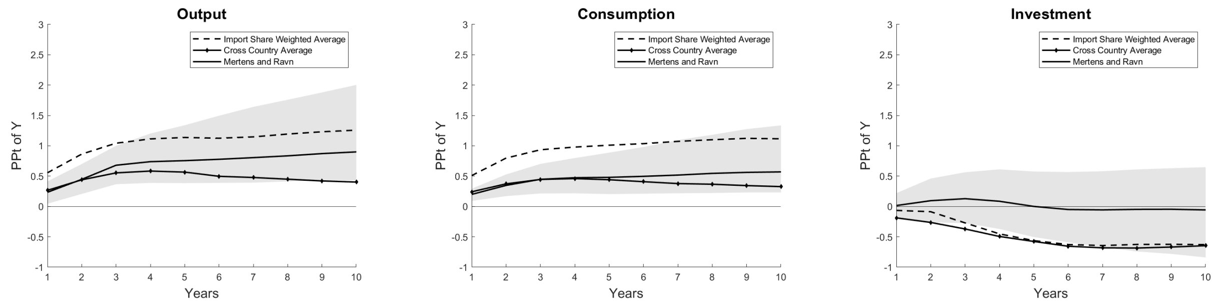
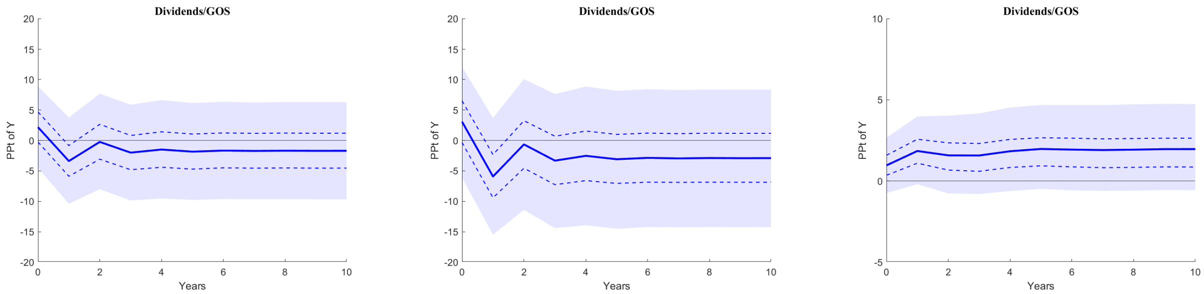


Figure 21: Comparison of international tax measures with narrative tax measure
Notes:: A shock to exogenous tax measures leads to a 1 percentage point cut in the country's corporate tax rate. Horizontal axes indicate years. Vertical axes measure percentage point deviation from aggregate value-added trend. Shaded areas indicate the 90 percent confidence bounds obtained by bootstrap sampling. Sample: the US, 1973-2006, annual data.

The impulse response functions for GDP per capita and consumption are close to the results of Mertens and Ravn (2013). GDP per capita increases by around 0.6 percent, and the rise in consumption is equivalent to a 0.5 percent point rise in GDP per capita. The cross-country average corporate tax rate gives the same results for the first two years for output and five years for consumption with narrative measure. In the long-run average corporate tax rate underestimates the responses. On the other hand, the import share weighted corporate tax rate is very close to the narrative measure, but it little overestimates the responses for output and consumption. In the long-run, international tax measures stay within the 90% confidence bounds of narrative measure. The response for the investment is zero for the narrative measure but negative for international tax rates. The differences between international tax rates and narrative measures may stem from the fact that the narrative measures are computed by summarizing the significant events of a potentially very large information set into account.

B.7 Dividends

To investigate the effect of a permanent tax cut on the ratio of dividend to Gross operating surplus (GOS), we consider a panel SVAR which includes the international corporate tax rate, investment as a share of GDP, dividend/GOS. OECD data is available from 1970 to 2017 for a few countries and for most of the countries between 1995 and 2017. We take both financial and non-financial corporations. Then we can check for each sub-sample: ES-SCAN and EU because the literature claims that a tax cut leads to an increase in dividends and no increase in investment.



(a) Whole Sample (b) ES. Scan. Countries (c) Cont. European Countries

Figure 22: Comparison of the effects of tax cut on Dividend/GOS

Notes:: A shock to exogenous tax measures leads to a 1 percentage point cut in the country's corporate tax rate. Horizontal axes indicate years. Vertical axes measure percentage point deviation from aggregate value-added trend. Shaded areas indicate the 90 percent confidence bounds obtained by bootstrap sampling. Sample: the US, 1973-2017, annual data.

Cloyne et al. (2023) find that goods producers increase employment and investment and services increase dividends instead of increasing employment. The effect of permanent cut on corporate tax rate has not a significant positive long run effect on Dividends to GOS ratio in both group of countries. Thus, we can claim that the unchanged R&D in Continental European Countries is not because they pay more on dividend when the corporate tax is reduced.