

# US corporate tax rate cuts: Spillovers to the Irish economy

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This paper shows that past US corporate income tax rate cuts created small but persistent positive spillovers to the Irish economy.



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# US corporate tax rate cuts: Spillovers to the Irish economy

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We examine spillovers to the Irish economy from US corporate income tax rate cuts and find they lead to a small but persistent increase in Irish economic output. Our analysis of the transmission channels shows that an increase in investment, employment and exports in the externally-financed industrial sector largely drives this expansion. We also find that output spillovers from US corporate income tax cuts are larger when there is slack in the Irish labour market. Our findings suggest that the changing structure of the Irish economy means any spillovers to real economic activity from the recent US corporate tax cuts could be relatively minor. However, the larger presence and shifting focus of foreign multinational corporations' operations in Ireland means lessons from past US corporate tax cuts may be of limited value in predicting the effects of the recent US tax system reform.

**Keywords:** Corporate tax shocks, cross-border spillovers, Irish economy.

**JEL codes:** E62, F23, F44

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# US corporate tax rate cuts: Spillovers to the Irish economy

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June 21, 2019

## Abstract

We examine spillovers to the Irish economy from US corporate income tax rate cuts and find they lead to a small but persistent increase in Irish economic output. Our analysis of the transmission channels shows that an increase in investment, employment and exports in the externally-financed industrial sector largely drives this expansion. We also find that output spillovers from US corporate income tax cuts are larger when there is slack in the Irish labour market. Our findings suggest that the changing structure of the Irish economy means any spillovers to real economic activity from the recent US corporate tax cuts could be relatively minor. However, the larger presence and shifting focus of foreign multinational corporations' operations in Ireland means lessons from past US corporate tax cuts may be of limited value in predicting the effects of the recent US tax system reform.

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# 1 Introduction

Ireland is one of the world's most Foreign Direct Investment (FDI)-intensive countries. Since revoking protectionist policies in the late 1950s, Ireland's economic growth model largely relies on attracting FDI. This policy has created substantial benefits for the Irish economy (Barry and Bradley, 1997), with foreign multinational corporations (MNCs) responsible for a considerable proportion of employment and output. FDI inflows can create technology spillovers that boost Irish productivity (Ruane and Ugur 2005) and lift Ireland up the world economy's value-added chain (Barry and Bergin, 2012). The presence of foreign MNCs also has a positive effect on the entry rate of domestic firms (Gorg and Strobl, 2002; Barrios et al., 2005). These benefits likely outweigh potential negatives of such large FDI flows, such as fears that these flows would reverse when needed most (Gorg and Strobl, 2003; Campa and Cull 2013). These fears proved unfounded during the recent financial crisis (Godart et al., 2012) and the drop in economic activity amongst foreign MNCs was less than experienced in domestic-dominated sectors (Department of Finance, 2014a).

In addition to its access to the EU single market, highly skilled, English-speaking workforce and solid institutions, Ireland's low corporate tax rate influences both the extensive (decision to locate) and intensive (scale of production) operations of foreign firms' in Ireland (Barry et al., 2003; Lawless et al., 2014). The recently-introduced Tax Cuts and Jobs Act (TCJA) reduced the headline United States (US) corporate income tax rate and has shrunk the corporate tax rate gap between Ireland and the US. Ireland's increasing reliance on US multinationals (National Competitiveness Council, 2018; Purdue, 2018) means this change in the US corporate tax system could diminish Ireland's attractiveness as a destination for FDI and is widely recognised as a risk to the Irish economy (Central Bank of Ireland, 2018; Department of Finance, 2018; European Commission, 2018a; International Monetary Fund, 2018).

In this paper, we use the local projections approach (Jorda, 2005) to analyse the dynamic response of the Irish economy to past US corporate income tax rate cuts. We first estimate the size of spillovers on aggregate Irish economic output, using the

narratively-identified shocks to the US corporate income tax rate produced by Mertens and Ravn (2013). We find that such tax cuts lead to a small but persistent increase in Irish output during our 1950-2006 sample period. We then take advantage of the flexibility of the local projections approach to examine the transmission channels through which these spillovers to aggregate economic activity occur. This reveals that an expansion in investment, employment and exports in the industrial sector largely drive the positive output spillovers. The financing for this economic activity is largely from external sources. A further advantage of the local projections approach is that it facilitates an assessment of non-linear effects. Our analysis of the state dependencies of spillovers from US corporate income tax cuts reveals that the spillovers are larger when there is slack in the Irish labour market.

Finally, we discuss the implications of our results for the potential impact of the US corporate income tax rate cuts introduced as part of the TCJA. We note that the changing structure of the Irish economy means that the same transmission channels that produced the positive spillovers may not be as strong today as they were in the past. In particular, our estimates suggest an increase in the external financing of Irish economic activity following a US corporate tax cut. One explanation for this is that Ireland's low capital stock implied a high marginal product of capital, which induced capital inflows despite the reduced tax liabilities from keeping these funds in the US. The nature of foreign MNCs' operations in Ireland has also changed. Presently, there is a disconnect between the balance sheets and real activities undertaken by these firms in Ireland. This could result in a capital outflow from the Irish economy following a reduction in US corporate income tax rates. It is also possible that the unprecedented size and speed of the US corporate income tax cut introduced as part of the TCJA exhibits some important threshold effects that we do not consider in this study.

We do not assess the past spillovers to Ireland from the other changes to the US tax system introduced as part of the TCJA. These include reductions in personal income taxes and a change from a worldwide to a territorial tax system. Although Mertens and Ravn (2013) also produce US personal income tax shocks using the narrative approach,

there are sunset clauses in the TCJA that eliminate these personal income tax cuts after 10 years. Thereafter, they become personal income tax increases. The linkage between changes in the US personal income tax system and the Irish economy is also less clear-cut than it is for changes in the US corporate tax system. Given the discrete nature of the shift to a territorial tax system, there are no historical instances from which to empirically assess the causal effects of this change.<sup>1</sup>

We next discuss the related literature, before explaining how we address the key empirical challenge of identifying the US corporate income tax shock in Section 3. In Section 4 we outline our empirical strategy for the estimation of spillovers from US corporate income tax shocks to the Irish economy, with a description of the dataset we use provided in Section 5. We present our estimated results in Section 6. We then discuss what our results imply for the potential spillovers from the US corporate tax cuts announced as part of the TCJA in Section 7. Finally, we summarise and conclude in Section 8.

## 2 Related literature

Our study is closely related to two important strands of literature. The first examines the spillovers from external shocks to the Irish economy. Given that Ireland is a very open economy, with highly-elastic supplies of capital and labour (Blanchard, 2002) and a quick pass-through of foreign into domestic prices (Geary and McCarthy, 1976; Callan and Fitzgerald, 1989; Bermingham, 2006), it is not surprising that there is a substantial literature assessing spillovers. These studies employ a wide range of techniques to analyse the effects of external shocks to the Irish economy, and generally find that they have a sizeable impact.

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<sup>1</sup>Mullins (2006) examines the implications of a shift in US tax policy from a worldwide basis to a territorial basis using semi-elasticities from De Mooij and Ederveen (2003). He concludes that this change could have significant implications, in terms of FDI flows, the intensity of tax competition and tax revenues, for those countries who source FDI from the US. Liu (2018) provides evidence that the UK's 2009 shift to a territorial tax system resulted in UK multinational corporations investing significantly more in low-tax jurisdictions. Using the Devereux and Griffith (2003) approach to measuring the effective average tax rate, Heinemann et al. (2017) estimate that low-tax jurisdictions like Ireland could become *more* attractive following the US move to a territorial tax system. Barry (2018) and Matheson and Kleinbard (2018) come to a similar conclusion.

McAleese and McCarthy (1989) and Barry and Bradley (1991) both quantify the impact of external shocks and find that the Irish policy response contributed to the unsatisfactory economic performance during the 1980s. Honohan and Leddin (2006) examine the size and effects of external shocks in the context of Ireland's entry into the Economic and Monetary Union (EMU). They find that the size of shocks did not increase substantially following the EMU accession. Barry and Devereux (2006) demonstrate using a neo-classical growth model that shocks to the external finance premium cannot explain the scale of growth during the Irish boom. Kanda (2008) finds that shocks to US output have a larger impact on Irish output than shocks to the euro area or UK output, using a vector autoregression (VAR). Bermingham and Conefrey (2014) also show that Irish economic growth is highly sensitive to the economic performance of its trading partners. Using a Bayesian-estimated VAR, they find that the Irish economy is most responsive to changes in euro area output, which is in line with Ireland's relative export shares. Clancy et al. (2016) use a Global Dynamic General Equilibrium model to demonstrate that Ireland's trade linkages do indeed affect the size of spillovers from external fiscal shocks. Their analysis shows a close relation between the size of spillovers and the response of aggregate euro area nominal interest and exchange rates, over which Ireland has no control.

O'Grady et al. (2017) use a Global VAR approach to show that unanticipated shocks to external macroeconomic factors have sizable and significant effects on the Irish economy. They reason that their results could reflect an inability of the Irish economy to adapt either economic policy or industry mix in response to changes in external conditions. Conefrey et al. (2018) demonstrate Ireland's exposure to external shocks using the COSMO structural macroeconometric model of the Irish economy (Bergin et al., 2017). Using a Bayesian VAR, Purdue (2018) estimates that the multinational sector is more sensitive to US output shocks than the domestic sector. Further analysis reveals that US shocks have larger spillovers to the Irish economy than those from the UK.

Our study also relates to the literature assessing the effect of the *Irish* corporate tax rate on Irish economic activity. On the theoretical front, Barry (2002) notes that the

importance of low corporate taxes to Ireland's growth model depends on whether one subscribes to the "delayed convergence" (Honohan and Walsh, 2002) or the "regional boom" (Krugman, 1997) hypothesis of Ireland's economic convergence. Under the former, Ireland could follow the same policies as the rest of the EU and still converge (Barry and Devereux, 2006). However, under the latter, non-orthodox policies such as Ireland's low corporation tax rate are a necessary element in ensuring convergence.

Empirical studies provide ample evidence of the importance of the Irish corporate tax rate. Gunnigle and McGuire (2001) find that the corporation tax rate is of critical importance in attracting US FDI to Ireland, using survey evidence from ten major US corporations and executives employed in the main industrial promotions agencies. Devereux et al. (2002) note that the dramatic increase in inward investment was one consequence of Ireland's low corporation tax rate on manufacturing activity. This boosted corporate income tax revenues as a share of GDP, despite having such a low rate. Lane (2002) attributes the rise in revenue to the substantial increase in the corporate tax base. Hines (2003) estimates that Ireland's corporation tax rate was well below that implied by Ireland's population, income and its membership of the EU.

Conefrey and Fitzgerald (2011) nest a model of the business and financial sector within the HERMES model of the Irish economy (Bradley et al., 1993) to explore the effects of changing the Irish corporation tax rate. They find that a corporate tax rate cut boosts output via an expansion in exports. This economic expansion occurs despite an increase in profit repatriations and is sufficient to offset the loss of tax revenue. In a panel of 26 European countries (including Ireland), Lawless et al. (2014) find that taxation is the most important determinant of multinational firms' location decisions. They simulate a counterfactual in which the Irish corporation tax rate had been higher between 2005 and 2012, and estimate that the number of new foreign affiliates entering the country would have been substantially lower.



### 3 US corporate income tax shocks

The endogeneity of changes in fiscal policy to current and expected economic conditions makes it difficult to identify truly exogenous fiscal shocks. The literature proposes two ways of overcoming this difficulty. The first is the estimation of innovations to fiscal variables as the difference between their realised values and those predicted using either structural VARs or fiscal rules. These methodologies use the institutional features of tax and transfer systems (Blanchard and Perotti, 2002) or sign restrictions from economic theory (Mountford and Uhlig, 2009) as identifying assumptions. They assume that discretionary fiscal policy does not respond contemporaneously to shocks to their macroeconomic determinants. However, this approach may misrepresent the timing and size of fiscal shocks. This is because economic agents may *anticipate* the fiscal shock picked up by the econometrician (Ramey, 2011). Thus, the adjustment may already be underway by the time the shock is diagnosed.

Beginning with Ramey and Shapiro (1998), many researchers have employed an alternative identification strategy, based on the selection of events representing exogenous changes to fiscal policy. This is referred to as the *narrative* approach. If these events are truly exogenous with respect to prevailing economic conditions, they provide quasi-natural experiments for the effect of fiscal policy changes. Romer and Romer (2010) use the narrative approach to construct a series of exogenous changes in US (total) tax liabilities. Their series measures the *expected* cumulative effect on federal tax revenue in the first year after the tax liability change. By considering only legislative actions motivated by ideology or arising from inherited deficit concerns, they argue that these changes in tax liabilities are unrelated to the current state of the economy and therefore represent exogenous tax shocks. Mertens and Ravn (2013) extend this narrative tax shock series by disaggregating it into personal and corporate income tax shocks. Given the distinct macroeconomic effects from unanticipated and anticipated tax changes (Mertens and Ravn 2011, 2012), they include only those tax changes for which the lag between legislation and implementation is less than one quarter. Unanticipated narrative tax shocks avoid the issue of fiscal foresight (Favero

and Giavazzi, 2012; Leeper et al, 2013).

Dividing these narrative corporate tax liability changes by (lagged) corporate profits allows for a conversion into average corporate income tax rate changes. Mertens and Ravn (2013) then use the (demeaned) narrative measure as a proxy for structural innovations to the average corporate income tax rate calculated from the US national accounts (NIPA), which suffer from several different sources of endogeneity.<sup>2</sup>

## 4 Empirical strategy

We estimate the dynamic effects of US corporate income tax shocks on the Irish economy using Jorda’s (2005) local projection method, a single equation approach to generating impulse responses that can match those produced by a VAR. Ramey (2016) demonstrates that this approach generates very similar results to the proxy SVAR analysis of (total) tax shocks in Mertens and Ravn (2014).<sup>3</sup> The Jorda (2005) approach estimates the impulse responses of a variable of interest  $Y$  at horizon  $h$ , given the same initial conditions:

$$Y_{t+h} = \alpha_h + \beta_h \epsilon_t + \phi_h(L)Z_{t-1} + \nu_{t+h} \quad (1)$$

where  $\beta_h$  is the estimate of the impulse response of  $Y$  at horizon  $h$  to a shock  $\epsilon_t$  and  $Z$  is a vector of relevant control variables. We exploit the flexibility of the local projections approach by estimating the dynamic response of a wide range of variables (*i.e.* by alternating the  $Y$ ) to US corporate tax shocks. As controls, in each regression we include lags of the narrative corporate income tax shocks and the dependent variable

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<sup>2</sup>The NIPA-based average corporate income tax rate is defined as federal taxes on corporate profits divided by corporate profits. See Mertens and Ravn (2013) for a discussion of the many different sources of endogeneity in the average corporate income tax rate calculated in this way.

<sup>3</sup>As a robustness check, we assess whether there are significant feedback effects from Irish GDP to the US variables examined by Mertens and Ravn (2013). The presence of such feedback would necessitate the modelling of the effects of US corporate tax cuts on the Irish economy as part of a system, rather than the single equation approach we propose. We find no evidence of feedback (see Appendix A for details). This is likely because US policymakers do not take the condition of, or the impact on, the Irish economy into account when changing US corporate tax policy. This further bolsters our claim that the US corporate tax shocks are exogenous to the Irish economy, and allows us to use the single equation local projections approach.

of interest, as well as the lags of Irish and US GDP.<sup>4</sup> We include the latter as a proxy for external demand. Each regression also includes a constant and a time trend (we discuss the inclusion of this latter variable in more detail later in this section). As there is a separate regression for each horizon, Ramey (2016) draws an analogy between the local projections approach and direct forecasting (Marcellino et al., 2006). She also points out that the error term is serially correlated because it is a moving average of the forecast errors from  $t$  to  $t + h$ . We therefore use the Newey-West (1987) serial correlation correction for the standard errors.

The local projections estimation procedure has several advantages. First, it is more robust to misspecification of the data generating process than a vector autoregression, where specification errors are compounded at each horizon.<sup>5</sup> Second, it allows us to estimate each endogenous variable individually rather than as a system. Because the local projections approach does not require that all variables enter all equations, it allows for more parsimonious model specifications and the use of time series of differing lengths. This helps us preserve valuable degrees of freedom and is especially important in facilitating the inclusion of additional variables to assess the transmission channel of the spillovers by avoiding the curse of dimensionality. Finally, the approach is particularly suited to the incorporation of state dependent responses to fiscal shocks (Auerbach and Gorodnichenko, 2013; Owyang et al., 2013; Broner et al., 2018; Ramey and Zubairy, 2018). Auerbach and Gorodnichenko (2013) and Blagrove et al. (2017) demonstrate that the state of the economy when the shock occurs can affect the magnitude of fiscal spillovers.

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<sup>4</sup>If the shocks are truly exogenous, then there is no need to include any variables beyond lags of the shocks and the dependent variable. However, to ensure our results are robust, we estimated the model with different combinations of control variables beyond what are strictly necessary. These include the aggregate GDP of all OECD countries as an alternative proxy for external demand and a dummy variable representing the signing of a Double Taxation Agreement between Ireland and the United States in July 1997. The latter could have an effect on Irish-US FDI flows over and beyond the US corporate tax rate (Davies, 2004; Barrios et al., 2012). We find that the set of additional controls makes little qualitative or quantitative difference to the results.

<sup>5</sup>The fewer dynamic restrictions means the local projections method is more robust to model misspecification errors than VARs. However, if the model is correctly specified, VARs are more efficient. Impulse responses estimated via local projections tend to have wider standard error bands. This issue is exacerbated by the volatility of the Irish economy, with O'Grady et al. (2017) noting that the size of the error bands around Irish impulse responses are larger than for other (larger) economies.

We estimate the model in log levels. This is despite the fact that many of the variables we use are nonstationary. Ramey (2016) notes that as long as the imposition of stationarity is not required for identification, the safest method to specify a model when variables may be (either deterministically or stochastically) trending is to estimate using log levels. A time trend can be included if thought necessary. Despite there being no strict need, we also include a (deterministic) time trend in all our regressions to guard against potential bias in our results.<sup>6</sup>

## 5 Data

Mertens and Ravn (2013) estimate a quarterly model using US data. Irish quarterly data is available since 1997. However, the US narrative corporate income tax shock series ends in the fourth quarter of 2006.<sup>7</sup> Therefore, there is insufficient Irish data to conduct a comprehensive empirical analysis at the quarterly frequency. Instead, we use (longer) annual series. We annualise the quarterly US narrative corporate income tax shock series to facilitate estimation in an annual model. To do so, we follow the same process as Mertens and Ravn (2013) when converting their quarterly narrative personal income tax shock series to an annual frequency.

We plot the average corporate income tax changes derived from the national accounts (blue line) and the narrative corporate income tax shocks (red line) in Figure 1. Despite moving together in some years, there is a negative correlation ( $\rho = -0.34$ ) between the two series, highlighting the differences in shocks from the two approaches. There are 15 narratively-identified corporate income tax shocks in total, ranging from

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<sup>6</sup>As a robustness check, we also estimated our regressions with the variables specified in first differences. Although this had a larger effect than the changing of the set of control variables, the differences were not sufficiently large as to overturn the main conclusions. Despite our belief (corroborated by the empirical evidence in Appendix A) that the US narrative corporate tax shock is exogenous to developments in the Irish economy, we also estimated the model using an instrumental variable regression. This provides further protection against biased results due to measurement error. More precisely, we use the narrative tax shock as an instrument for the change in the average corporate income tax rate. This broadly follows Ramey (2016), who converts Mertens and Ravn (2014)'s proxy SVAR analysis on (total) tax shocks into a local projections framework estimated using instrumental variables. The use of this alternative empirical methodology has little qualitative effect on the results.

<sup>7</sup>The last non-zero observation (i.e. US corporate tax shock) is in 2003. Therefore, there are several years between the end of the sample and the final shock from which to estimate the dynamic responses.

an increase of 8-percentage points in 1986 to a decrease of 2.5-percentage points in 1971.<sup>8</sup> The year, sign and size of the shocks are provided in Table 1. Ten of the shocks represent tax cuts, which tend to occur earlier in the sample. The more recent part of the sample largely contains corporate tax increases.

Before assessing the spillovers to the Irish economy, we first replicate Mertens and Ravn's (2013) proxy SVAR model to assess whether transforming the narrative corporate income tax shocks to an annual frequency has altered their results. We find that a 1-percentage point corporate tax cut has a positive effect on U.S. output that peaks after 3 years at roughly 0.7 percent of GDP (Figure 2). The effect is quite persistent, with a statistically significant (at the 90% level) increase in output throughout the entire four-year horizon. Consistent with the findings from Mertens and Ravn's (2013) quarterly model, the strong response of the corporate income tax base means that the cut in the corporate income tax rate does not decrease corporate tax revenues (result not shown).<sup>9</sup>

In order to take full advantage of the long series of US corporate income tax rate shocks, we need to go beyond the Irish national accounts (available since 1970) provided by the Irish Central Statistics Office. Therefore, we make use of the ESRI Data-bank of Economic Time Series. This dataset also contains a wide range of series used in the construction of the HERMES model of the Irish economy (Bergin et al. 2013), allowing us to conduct a comprehensive examination of the transmission channels of spillovers from US corporate income tax shocks. Where necessary, we source additional data from a historical macroeconomic database for Ireland produced by Rebecca Stuart and others in a series of papers (Gerlach and Stuart, 2013; 2015; Gerlach et al., 2016; Stuart, 2017a).<sup>10</sup>

We document the series used in the empirical analysis in Table 2. Our sample ends

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<sup>8</sup>Mertens and Ravn (2013) narratively identify 16 quarterly corporate tax shocks. However, two shocks occur in 1962, which we sum to get the annualised size of the shock in that year.

<sup>9</sup>Mertens and Ravn (2013) note that the highly elastic nature of the US corporate tax base prevents the calculation of corporate tax *multipliers*, i.e. the change in output for a given change in corporate tax revenues. The elastic response of the US corporate tax base means the change in corporate tax revenues is close to zero.

<sup>10</sup>The compilation of the database is described in Stuart (2017b). The database itself is available for download at <http://rebeccastuart.net/historical-macroeconomic-data/>.

in 2006, the last year of the Romer and Romer (2010) narrative dataset upon which Mertens and Ravn (2013) build their narrative corporate income tax shock. We only use series that start no later than 1961 (so, a minimum of 45 years of data) in order to preserve as many observations as possible to facilitate accurate estimation. Only one US corporate tax shock occurs before 1961. We convert all nominal series into real terms using the relevant deflators, and population data from the census to transform the variables into per-capita terms. Since the census is conducted every five years, we follow the approach of Gerlach and Stuart (2015) and interpolate the missing years using a cubic spline.

## 6 Estimated spillovers

We estimate the dynamic response of key Irish economic variables of interest for four years after a US corporate income tax cut.<sup>11</sup> We first examine aggregate measures of Irish economic output. The top-left panel in Figure 3 shows that a 1-percentage point cut in the U.S. corporate tax rate leads to an annual increase of around 0.01 percent in Irish GDP on impact.<sup>12</sup> This effect is persistent and statistically significant at the 90 percent level for two years following the shock. There is no appreciable rise in net factor income flows, and therefore Gross National Product (and Gross Value Added) have a very similar response to GDP in terms of size, persistence and significance.

The estimated output spillovers may seem relatively small, in part because we only examine a 1-percentage point cut in the US corporate tax rate.<sup>13</sup> It is possible that larger tax cuts have important threshold effects. Djankov (2017) notes that double-digit cuts in the corporate income tax rate (such as that enacted as part of the TCJA)

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<sup>11</sup>Ramey (2012) shows that the equivalence in the impulse responses estimated using local projections and VARs begins to break down after 16 quarters.

<sup>12</sup>We estimate a slightly lower point estimate of the impulse responses if we instead use the longer GDP (index) series provided by Stuart (2017b). This difference in estimates suggests that the US corporate tax shock that occurred during the 1950s may have had a smaller effect on Irish output than those that followed, in line with Ireland being a less open economy during that period.

<sup>13</sup>Many studies in the fiscal policy spillovers literature scale their shocks to represent a 1% increase in GDP in the source economy. However, following such a procedure would require imposing a far larger cut to US corporate tax rates than occurred during our sample period. We therefore prefer to examine a 1-percentage point cut in the US corporate tax rate, which is close to the average tax cut in our dataset.

are a rare occurrence in advanced economies. He also points out that corporate income tax changes of this magnitude usually take years to implement and are introduced gradually. Lawless et al. (2014) find that there are non-linear effects from changes in corporation tax rates depending on whether the initial rate is high or low. Changes to already-low tax rates have larger effects than those to existing high rates. Future work could assess whether any threshold effects are present in the spillovers from US corporate income tax shocks to the Irish economy. However, the relatively small number of exogenous US corporate tax cuts is a limiting factor in this regard.

## 6.1 Transmission channels

We next take advantage of the flexibility of the local projections approach to estimate the dynamic response of a wide range of Irish economic variables to US corporate income tax cuts to ascertain the transmission channels through which these shocks spill over to the Irish economy. We begin by estimating the response of the expenditure components of GDP to a 1-percentage point cut in the US corporate tax rate (Figure 4). We find that this shock leads to an expansion in all the components, with the rise in investment particularly prominent. Government expenditure rises significantly throughout the projection horizon, while consumption has a mild increase that loses significance after the first year. Net exports rise on impact, but this effect is only significant four years after the shock.

One explanation for this delayed impact on net exports is an offsetting rise in imports, particularly those used as intermediate inputs in the production of exports. However, Figure 5 shows this is not the case. Aggregate exports rise slowly and are not statistically significant at any horizon (Figure 6). Instead, it appears that the rise in exports is confined to the industrial sector. Given that this sector is dominated by foreign multinational corporations, especially those from the US, it is unsurprising that it would have the largest response to a US corporate tax cut.

An examination of sectoral investment reveals a similar pattern, with a more persistent rise in investment in the industrial sector (Figure 7). That there is a lag between

the expansion in investment and the increase in exports is consistent with the time-to-build hypothesis (Kyland and Prescott, 1982), whereby investment in new capital requires time to become productive. The rise in housing investment is insignificant at all horizons, while there is a large and statistically significant rise in Irish services investment in the two years following a US corporate tax cut.

Figure 8 shows that Irish gross national savings and private sector credit do not rise significantly following a US corporate income tax shock. In terms of domestic sources of finance, only IDA grants (results not shown) rose significantly after four years, implying that the (at least initial) financing for the rise in investment came from abroad.<sup>14</sup> Although we do not have sufficiently long time series to examine the different components of the balance of payments, we can see from the inflow in private sector capital transfers that some financing for the rise in investment did indeed come from abroad. Profit repatriations do not rise in line with activity in the foreign multinational-dominated industrial sector. This suggests that foreign multinational firms may have used retained earnings to finance some of the expansion in Irish investment.

The positive spillovers from US corporate tax cuts are not limited to capital inputs. There is also a statistically significant rise in total employment (Figure 9). Looking at the sectoral employment breakdown, we again find that the industrial sector responds the most strongly to a cut in US corporate taxes. The unemployment rate falls on impact, but the effect is not statistically significant, before eventually rising significantly after four years likely due to increases in the labour force and/or the participation rate.

Another explanation for the subdued (aggregate) export response is that an increase in Irish economic activity following a cut in the US corporate income tax rate causes a loss of competitiveness in Ireland. We find that prices rise on impact and continue rising through the projection horizon, with this effect becoming significant one year after the shock (Figure 10). Ireland's effective exchange rate also appreciates, although this effect is only significant after four years. Wages rise on impact but this increase is not significant at any horizon. However, and again in line with the time-to-build

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<sup>14</sup>The suggestion to examine the role of IDA grants as a domestic source of financing came from participants at the Barrington Lectures, who are kindly thanked for these very useful suggestions.



hypothesis, unit labour costs in the industrial sector rise. This is because there is an immediate expansion in employment, but the rise in investment takes time to filter into the capital stock (not shown).

Finally, we examine the effects of a US corporate income tax cut on Irish public finances (Figure 11). Walsh (2011) and Coffey (2015) document the significance of US companies as sources of Irish tax revenue. Despite the increased activity in the industrial sector (dominated by multinationals) and the lack of an increase in repatriated profits, there is no corresponding rise in Irish corporation tax revenue. This is consistent with the use of retained earnings for investment. The rise in broader Irish economic activity leads to an increase in government revenues. This offsets the rise in government expenditure, and therefore there is no increase in the budget deficit or public debt from a US corporate income tax cut during our sample period.

## 6.2 State-dependent spillovers

Our results provide a measure of the *average* effect of US corporate income tax changes on the Irish economy during our sample period. We next examine if the size of spillovers vary according to the state of the US and Irish business cycle. Larger spillovers from external fiscal policy changes during times of economic slack is a key result from Auerbach and Gorodnichenko's (2013) and Blagrove's et al. (2017) studies using panels of advanced economies. To assess the effect that different states of the economy have on spillovers from US corporate income tax cuts, we follow an approach developed by Auerbach and Gorodnichenko (2012). They construct a measure that represents a probability of being in a recession given the state of the business cycle:

$$F(z_t) = \frac{\exp(-\gamma z_t)}{[1 + \exp(\gamma z_t)]} \quad (2)$$

where they use a moving average of GDP growth as the variable that defines the state of the business cycle  $z_t$  and then calibrate  $\gamma$  to match the approximate percentage of the time the US economy spends in a recession (roughly 20%). Because Alloza (2017) showed that Auerbach and Gorodnichenko (2012)'s use of forward-looking informa-

tion to define the current business cycle states can bias the results, we instead use a backward-looking moving averages. We normalise  $z_t$  to have zero mean and unit variance and then calibrate  $\gamma$  so that the measure takes a value of 1 when the US (alternatively, Irish) economy was in recession (i.e. a negative growth rate).

We plot our state indicator variables  $F(z_t)$  for the US and Ireland in Figures 12 and 14 respectively. Our state indicator variables match US and Irish recessionary periods quite well. We then modify our local projections regression so that the impulse responses can vary depending on the state of the economy:

$$Y_{t+h} = F(z_{t-1}) [\alpha_{A,h} + \beta_{A,h}\epsilon_t + \phi_{A,h}(L)Z_{t-1}] + (1 - F(z_{t-1})) [\alpha_{B,h} + \beta_{B,h}\epsilon_t + \phi_{B,h}(L)Z_{t-1}] + \nu_{t+h} \quad (3)$$

where we transform our lagged state indicator variable into a dummy variable that is one when there is a higher probability of being in a recession (i.e. when  $F(z_{t-1}) > 0.5$ ). The  $\beta_{A,h}$  now represents the impact of a US corporate income tax cut when the US (alternatively, Irish) economy is (probably) in a recession. The  $\beta_{B,h}$  shows the response when the economy is (probably) expanding.

The spillovers to Irish output from shocks that occur during US recessionary and expansionary states are detailed in Figure 13. Although we find that the spillovers from US corporate income tax shocks are larger when the US economy is (probably) in recession, the difference between the state-dependent output responses is statistically insignificant.

The results in Figure 15 show that the positive response in GDP is driven by the response of the Irish economy during *expansions*. This runs counter to the recent literature that shows that spillovers from external fiscal stimuli are larger when there is slack in the recipient economy.<sup>15</sup> The statistical significance of the estimated difference

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<sup>15</sup>As robustness tests, we examined several different ways of measuring GDP-based states of the Irish business cycle. These include using deviations from trend GDP derived from both a HP filter and a polynomial trend. These alternative measures of the state of the Irish business cycle suggest the opposite; that spillovers are larger during Irish recessionary periods. However, these alternative

between the dynamic responses from the recessionary and expansionary states shows that the spillovers from US corporate income tax cuts are indeed larger when GDP growth is positive.

One possible explanation for this counterintuitive result is that GDP does not accurately represent the underlying state of the Irish economy. Therefore, we next examine a series of labour market variables to assess whether the spillovers from US corporate income tax cuts depend on the degree of slack in the Irish economy.<sup>16</sup> Researchers often use labour market variables to define periods of economic slack in state-dependent analyses of fiscal policy (Ramey and Zubairy, 2018). Figures 16, 17 and 18 demonstrate that greater slack in the labour market, as indicated (respectively) by below average employment growth and net migration and an above average unemployment rate, result in larger positive spillovers to the Irish economy from US corporate tax cuts.

## 7 Implications

Our analysis demonstrates the positive output spillovers to the Irish economy from US corporate income tax cuts. We find that these spillovers from past US corporate income tax cuts were primarily driven by a large investment, employment and export response in the externally-financed industrial sector. One explanation for these effects is that the initially low capital stock in this sector necessitated a rise in investment and employment once foreign MNCs began to shift operations to Ireland. As such, a high marginal product of capital may have induced capital inflows following US corporate income tax cuts. If this is indeed the transmission channel of the positive spillovers, the large *scale* of foreign MNCs operations in Ireland today means that this process may not be replicable.

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measures do not match Irish recessionary periods very well. There are also numerous statistical issues with using a HP filter to estimate the cyclical position of the Irish economy (Clancy 2013, Casey 2019).

<sup>16</sup>The suggestion to explore state-dependent spillovers using these labour market metrics came from participants at the Barrington Lectures. Data limitations prevented an examination of other proposed measures to define the state of the economy, including house prices and balance of payments components. The latter would allow for a direct test of our finding that externally-financed investment was the primary channel for the positive output spillovers. It would also facilitate a direct test of whether the spillovers grew larger as the degree of FDI in Ireland increased. We thank the participants for these very useful suggestions.

Ireland has already undergone the transition from a relatively closed, agricultural-based economy to a very open, advanced economy. Assuming these foreign MNCs are primarily located in Ireland for real economic reasons (and not just for tax avoidance purposes), the recent US corporate income tax cuts are more likely to affect the *intensive* margin of foreign MNCs operations in Ireland rather than *extensive* margin of whether they operate in Ireland or not. If the marginal product of capital is not as high as it was in the past, a US corporate tax cut is less likely to induce capital inflows. This implies that crowding out effects from the domestic resources needed to finance the increase in investment could result in smaller spillovers. Indeed, our state-dependent analyses demonstrate that spillovers are larger during times of labour market slack, which is not the case at the moment.<sup>17</sup> Moreover, the increased reliance on corporation tax revenues in recent years means that the Irish public finances are likely more exposed to changes in US corporate tax rates than our estimates imply.

Furthermore, the *type* of foreign MNCs operations has also changed dramatically since the end of our sample. The balance sheet activities of these corporations have recently begun to cause major distortions to the Irish national accounts and balance of payments statistics.<sup>18</sup> The onshoring of intellectual property assets, for example, has led to sizable increases in the size of the Irish economy (and expenditure components) without any corresponding effect on underlying economic activity. This disconnect implies that there is a greater amount of capital than necessary to support these foreign MNCs economic activity, and therefore a cut to US corporate income tax rates could induce a capital outflow from the Irish economy.

The focus of recent studies has been exclusively on the effects on US corporate tax

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<sup>17</sup>Although data limitations prevented us from examining the role of prevailing Irish house prices on the size of US corporate tax cut spillovers, Agnew and Lyons (2018) provide empirical evidence that increased FDI employment leads to a rise in Irish rents and house prices. The current strong rent and house price growth in Ireland therefore suggests that housing constraints could mitigate the positive spillovers witnessed in the past. Emerging infrastructural bottlenecks (European Commission, 2018b) could also diminish the potential for positive spillovers from the recent US corporate tax cut. As pointed out to us by participants at the Barrington Lectures, the spatial clustering of FDI in Ireland would likely exacerbate this issue.

<sup>18</sup>Of course, the relatively large presence of foreign MNCs has long created issues with GDP as a measure of the aggregate size of the Irish economy. However, recent changes to Ireland's tax residency rules and the introduction of new statistical standards for the national accounts and balance of payments have exacerbated these issues (Connolly, 2018).

changes on the balance sheet activities of foreign MNCs, rather than on their macroeconomic effects. Matheson and Kleinbard (2018) examine the effect of two aspects of the US corporate tax reform, the cut in the statutory corporate income tax rate and the expensing of capital investment, on Irish FDI inflows and corporate income tax revenues. To do so, they use a range of semi-elasticities of the corporate tax base, the percentage change in the corporate tax base following a 1-percentage point change in the corporate tax rate, produced by De Mooij and Ederveen (2008) and Beer et al. (2018a, 2018b). They estimate an average *reduction* in FDI inflows of 10.0 percent, with a minimum effect of 1.4 percent and a maximum of 30.5 percent. Given that our estimates of positive spillovers are partly from capital inflows, any capital outflow as a result of the recent changes would likely reduce or potentially overturn these positive spillovers that resulted from past US corporate tax rate cuts.

Matheson and Kleinbard (2018) note that their estimates are heavily dependent on the underlying assumptions for the proportion of Irish corporate profits accounted for by US firms and the size of the semi-elasticities. De Mooij and Ederveen (2008) and Beer et al. (2018b) derive their investment and profit semi-elasticities from meta regression analyses. These give a good indication of what the *average* semi-elasticity is from a broad group of countries and sample periods. Although they may not accurately capture the high degree of integration of US firms operating in Ireland, using a range of semi-elasticities provides greater protection from the issues surrounding the use of reduced-form estimates for policy analysis noted by Lucas (1973).<sup>19</sup>

## 8 Conclusion

Ireland's growth model has long relied on attracting FDI. This strategy has paid dividends and has helped propel Ireland's convergence to a modern, advanced economy.

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<sup>19</sup>Because policy changes can result in changes to economic agents' *expectations*, Lucas (1973) pointed out that econometric models based on historical data are of limited use for assessing the effect of future policy analysis. Since we use narratively-identified shocks that are exogenous to the Irish economy, our estimates are *structural* and can be reliably used for causal inference of *past* spillovers to Ireland from US corporate tax cuts. However, we cannot use these shocks to empirically estimate the potential effect of the TCJA on the Irish economy.

However, the heavy reliance on US multinational corporations has led to concerns that the recent cuts to the US corporate income tax rate could diminish Ireland's attractiveness as a destination for FDI. These cuts are therefore widely seen as a risk to the Irish economy.

We use the local projections approach (Jorda, 2005) to analyse the dynamic response of the Irish economy to past US corporate income tax rate cuts. We first estimate the size of spillovers on Irish aggregate economic output. We ensure we can make causal inferences by using the narratively-identified exogenous shocks to the US corporate income tax rate produced by Mertens and Ravn (2013). We find that they lead to a small but persistent increase in Irish output. We then take advantage of the flexibility of the local projections approach to examine the transmission channels through which these spillovers occur. We find that an expansion in investment, employment and exports in the industrial sector largely drive the positive output spillovers. The financing for this economic activity appears to be largely external. One explanation for this is that Ireland's low capital stock induced a capital inflow following a US corporate income tax cut. A further advantage of the local projections approach is that it facilitates an assessment of non-linear effects. Our analysis of the state dependencies of spillovers from US corporate income tax shocks reveal that the spillovers are larger when there is slack in the Irish labour market.

Finally, we discuss the implications of our results for the potential impact of the US corporate income tax rate cuts introduced as part of the TCJA. We note that the changing structure of the Irish economy means that the same transmission channels that produced the positive spillovers may not be as strong today as they were in the past. In particular, Ireland's much larger capital stock implies a lower marginal product of capital than in the past and therefore the reduced tax liabilities in the US may lead to a capital outflow. The changing nature of foreign MNCs' operations in Ireland will likely also have an effect. Some of the excess capital on their Irish balance sheets could also be repatriated to the US following a reduction in US corporate income tax rates. Finally, the unprecedented size and speed of the US corporate income tax cut

introduced as part of the TCJA may result in some threshold effects that we do not consider in this study.

It is somewhat surprising that US corporate income tax cuts lead to a capital inflow into Ireland (during our sample period). Future work could examine this aspect more closely. One approach would be to collect sufficiently long time series for the Irish balance of payments that allows for a breakdown of the current and capital accounts into their subcomponents. Stable capital inflows for the purpose of real economic activity should be less sensitive to changes in the US corporate income tax rate and more related to the expected return on capital. This would allow for a more direct test of whether our explanation is correct. Another approach is to condition the spillovers on the state of the current account (when it is in surplus versus deficit, for example). Again, if our explanation is correct, the spillovers should be larger when US corporate tax shocks occur and there is a deficit in the current account. We are unaware of a sufficiently long time series that would facilitate such an analysis.

Finally, we examine the effect of spillovers for cuts in the *US* corporate tax. However, changes in the Irish corporation tax rate can also create differences in the *gap* between the tax rates in the two jurisdictions. Estimating a causal inference from changes in the Irish-US corporation tax rate *gap* would require the isolation of the exogenous changes in the Irish corporation tax rate, such as via the narrative approach.<sup>20</sup> However, then one could potentially also need to consider the tax rates in other countries competing with Ireland for US foreign direct investment. Instead, our modelling approach implicitly assumes the choice facing US multinationals is how much to invest in the US versus how much to invest abroad. We believe this is the most suitable measure for the research question we examine.

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<sup>20</sup>It is worth noting that Ireland's manufacturing sector tax rate was stable over a very long period until the early 1990s. Conefrey and Fitzgerald (2011) note that this makes it infeasible to estimate the impact of this tax rate over a long time horizon. They overcome this issue by using the extension of the low manufacturing tax rate to the rest of the economy as a natural experiment in order to draw inference on the effects of changing the Irish corporate tax rate.

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## 10 Tables

TABLE 1. US corporate tax shocks

<b>Year</b>	<b>Size</b>
1954	-0.85
1962	-2.10
1964	-1.48
1967	-1.03
1971	-2.70
1972	-0.81
1976	1.25
1977	-0.05
1979	-1.97
1981	-1.43
1984	1.80
1986	8.16
1988	2.68
1991	1.01
2003	-2.50
Average	-0.13
Average cut	-1.65
Average rise	2.98

*Notes:* Annualised narratively-identified US corporate tax shocks based on the quarterly series produced by Mertens and Ravn (2013).



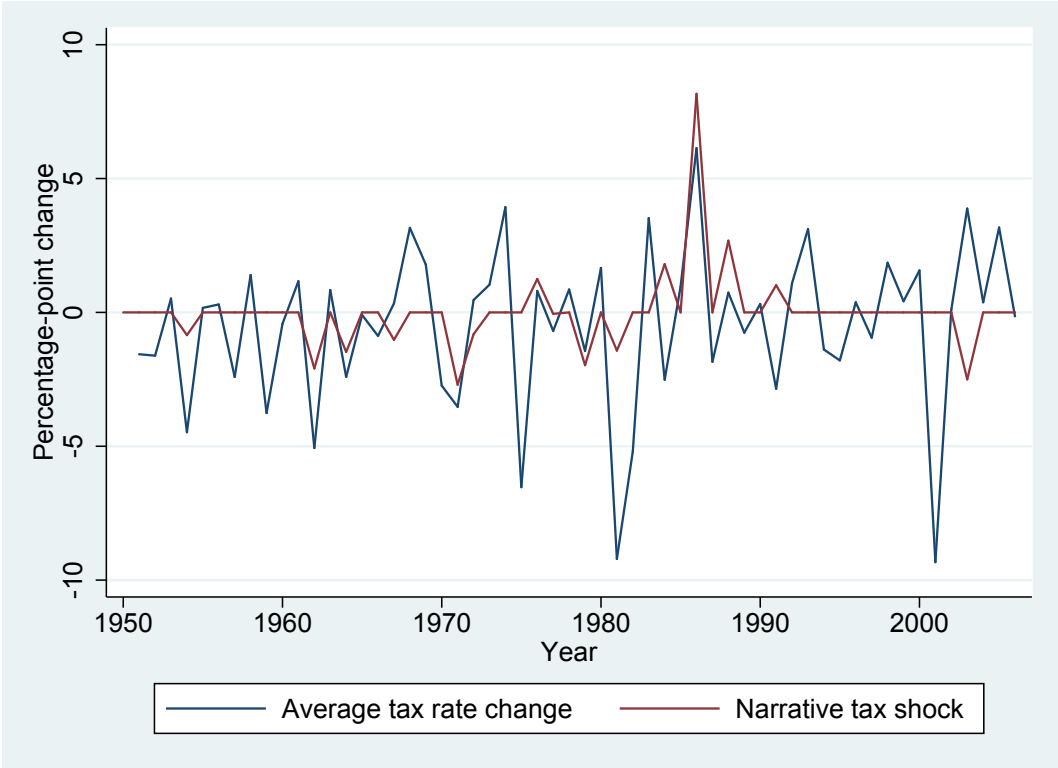
TABLE 2. Data description

Variable	Coverage	Source
Budget deficit	1960-2006	ESRI Databank
Consumer Price Index	1950-2006	Stuart (2017b)
Corporation tax revenue	1960-2006	ESRI Databank
Effective exchange rate	1960-2006	ESRI Databank
Goods exports	1950-2006	ESRI Databank
Goods imports	1950-2006	ESRI Databank
Government expenditure	1959-2006	ESRI Databank
Gross domestic product	1961-2006	ESRI Databank
Gross national product	1961-2006	ESRI Databank
Gross national savings	1960-2006	ESRI Databank
Gross value added	1961-2006	ESRI Databank
Housing investment	1953-2006	ESRI Databank
Industrial employment	1951-2006	ESRI Databank
Industrial exports	1958-2006	ESRI Databank
Industrial investment	1950-2006	ESRI Databank
Industrial unit labour costs	1960-2006	ESRI Databank
Labour force	1951-2006	ESRI Databank
National debt	1960-2006	ESRI Databank
Private sector capital transfers	1960-2006	ESRI Databank
Private sector credit	1950-2006	Stuart (2017b)
Private sector current transfers	1958-2006	ESRI Databank
Profit repatriations	1958-2006	ESRI Databank
Services exports	1960-2006	ESRI Databank
Services imports	1960-2006	ESRI Databank
Services investment	1953-2006	ESRI databank
Total investment	1960-2006	ESRI Databank
Total employment	1951-2006	ESRI Databank
Total exports	1960-2006	ESRI Databank
Total imports	1960-2006	ESRI Databank
Total wages	1950-2006	Stuart (2017b)
Unemployment rate	1950-2006	Stuart (2017b)
US Average corporate tax rates	1950-2006	Mertens and Ravn (2013)
US Gross domestic product	1950-2006	Ramey and Zubairy (2018)
US Narrative corporate tax shocks	1950-2006	Mertens and Ravn (2013)
US Population	1950-2006	Ramey and Zubairy (2018)

*Notes:* All variables included in the regressions are transformed into real per-capita terms, expressed in logarithms where possible. We source the five-yearly population data from the Central Statistics Office and interpolate it into an annual series (see Section 5 for details). We convert nominal variables into real terms using the relevant deflators, sourced from the ESRI Databank.

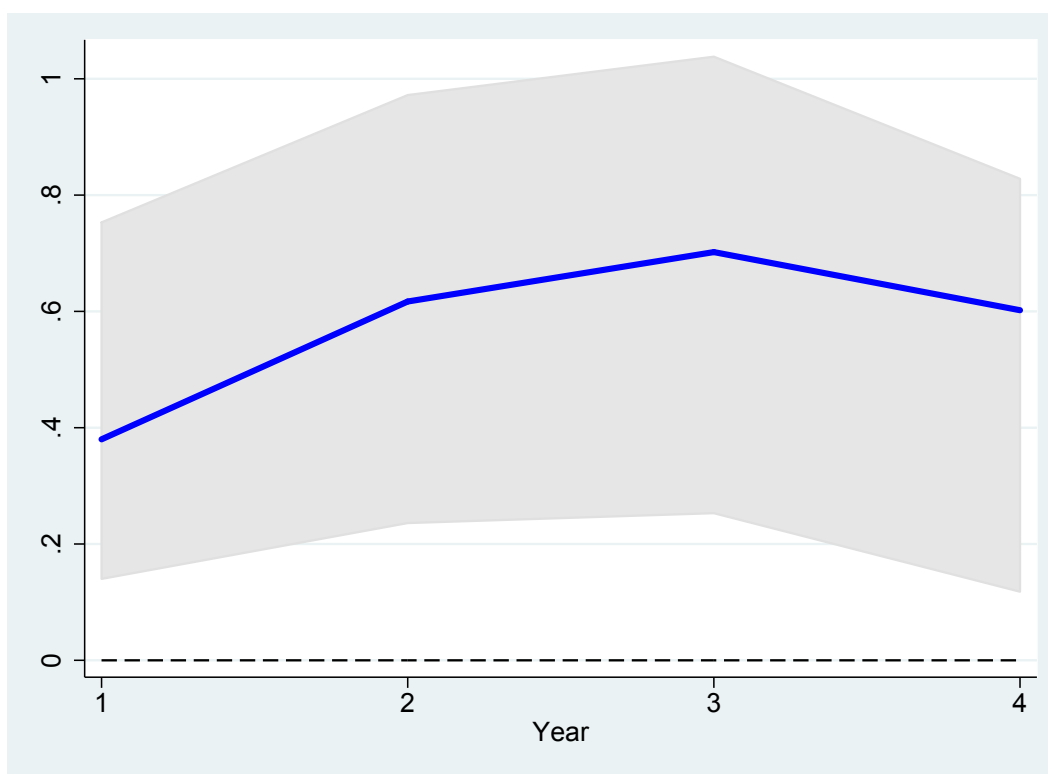
# 11 Figures

FIGURE 1. US corporate tax shocks



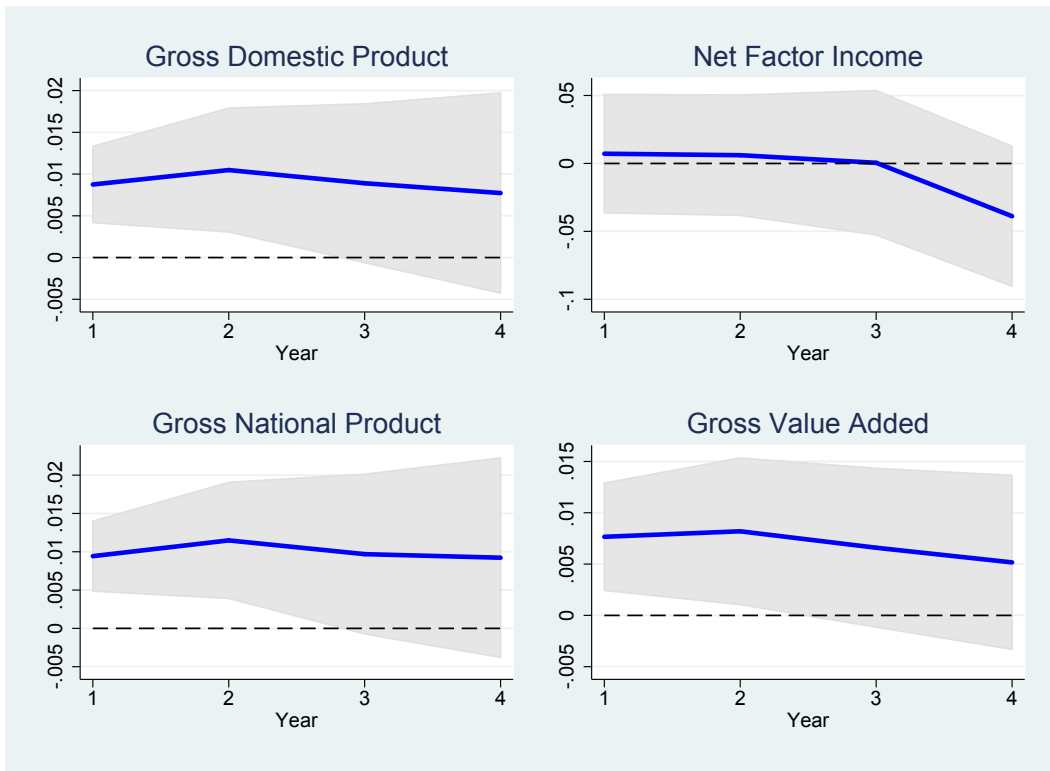
Notes: Annualised representation of the narrative corporate income tax shocks (red line) and changes in the average corporate income tax rate derived from the national accounts (blue line). We use the narrative shocks for our empirical analysis due to the endogeneity inherent in average corporate tax rate changes. Sources: Mertens and Ravn (2013) and authors' calculations.

FIGURE 2. US output response



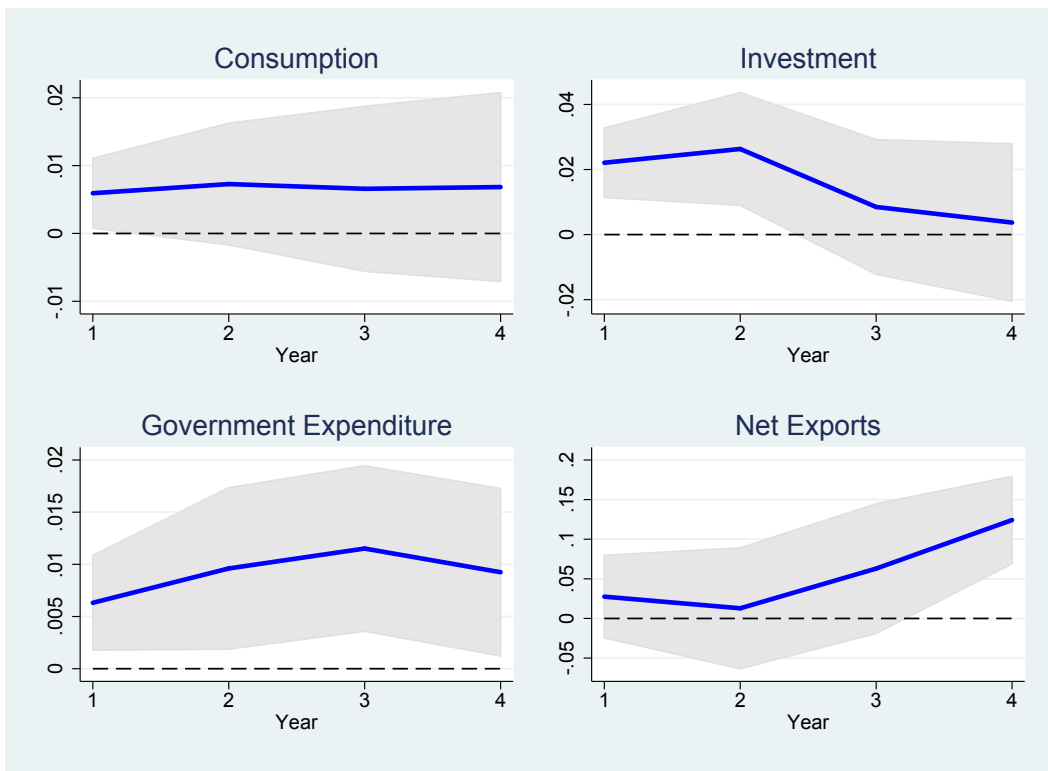
*Notes:* The solid line represents the estimated impulse response of US GDP following a 1-percentage point decrease in the US corporate income tax rate. The shaded area contains the 90 percent confidence intervals. For consistency, we use the same proxy SVAR approach and model specification as Mertens and Ravn (2013) to produce these impulse responses.

FIGURE 3. Spillovers to Irish output



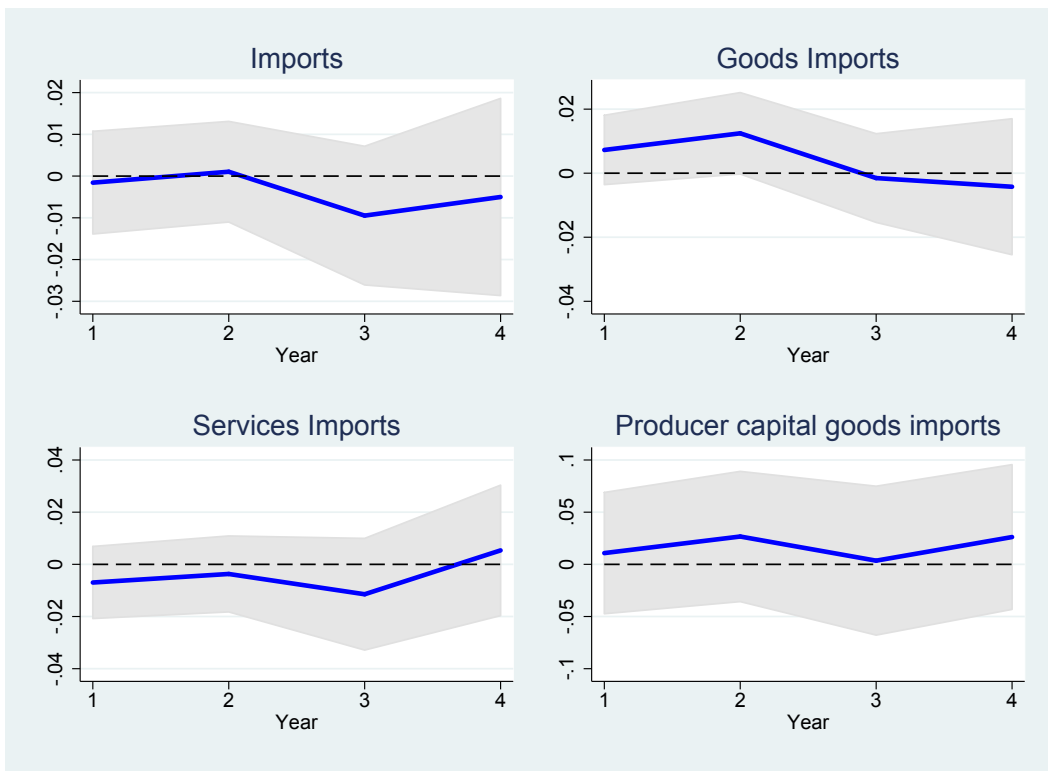
Notes: The solid lines represent the estimated impulse responses following a 1-percentage point decrease in the US corporate income tax rate. The shaded areas contain the 90 percent confidence intervals.

FIGURE 4. Spillovers to Irish expenditure components



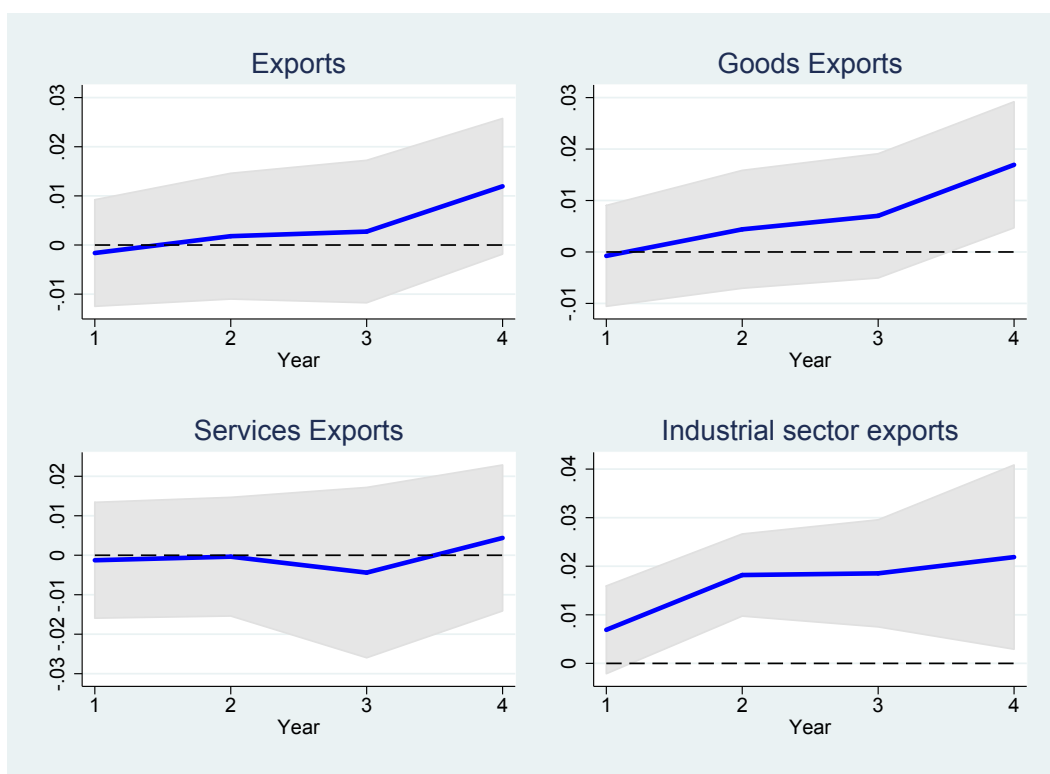
Notes: The solid lines represent the estimated impulse responses following a 1-percentage point decrease in the U.S. corporate income tax rate. The shaded areas contain the 90 percent confidence intervals.

FIGURE 5. Spillovers to Irish imports



Notes: The solid lines represent the estimated impulse responses following a 1-percentage point decrease in the U.S. corporate income tax rate. The shaded areas contain the 90 percent confidence intervals.

FIGURE 6. Spillovers to Irish exports



Notes: The solid lines represent the estimated impulse responses following a 1-percentage point decrease in the U.S. corporate income tax rate. The shaded areas contain the 90 percent confidence intervals.

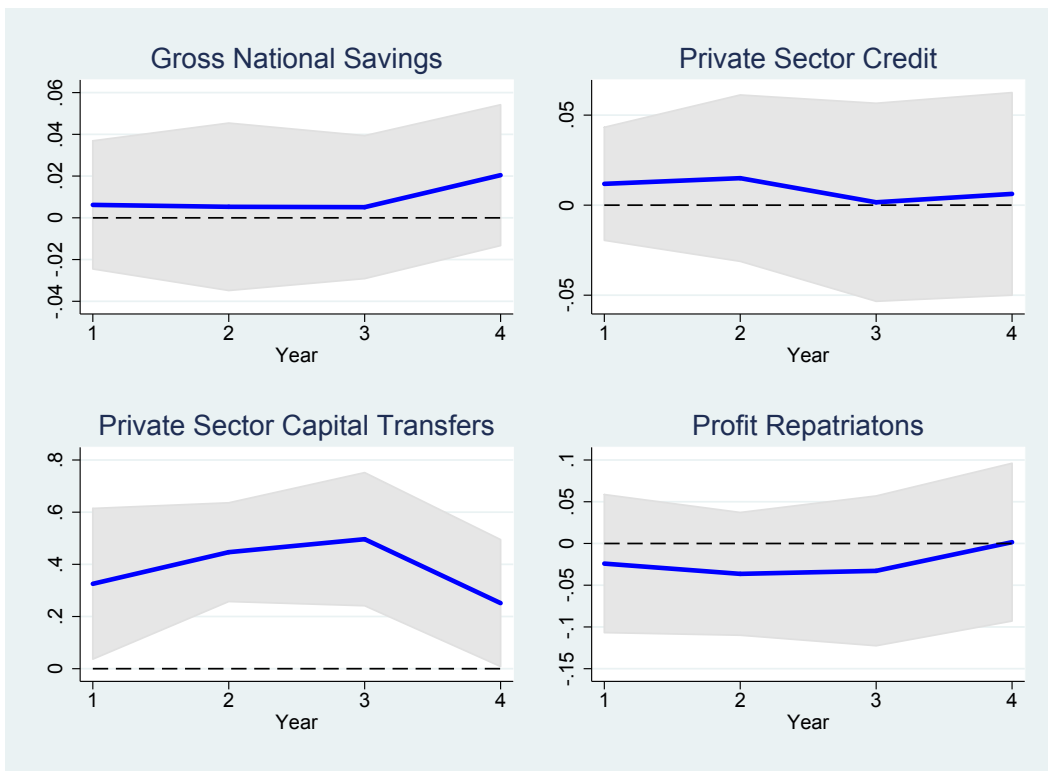
FIGURE 7. Spillovers to Irish investment



Notes: The solid lines represent the estimated impulse responses following a 1-percentage point decrease in the U.S. corporate income tax rate. The shaded areas contain the 90 percent confidence intervals.

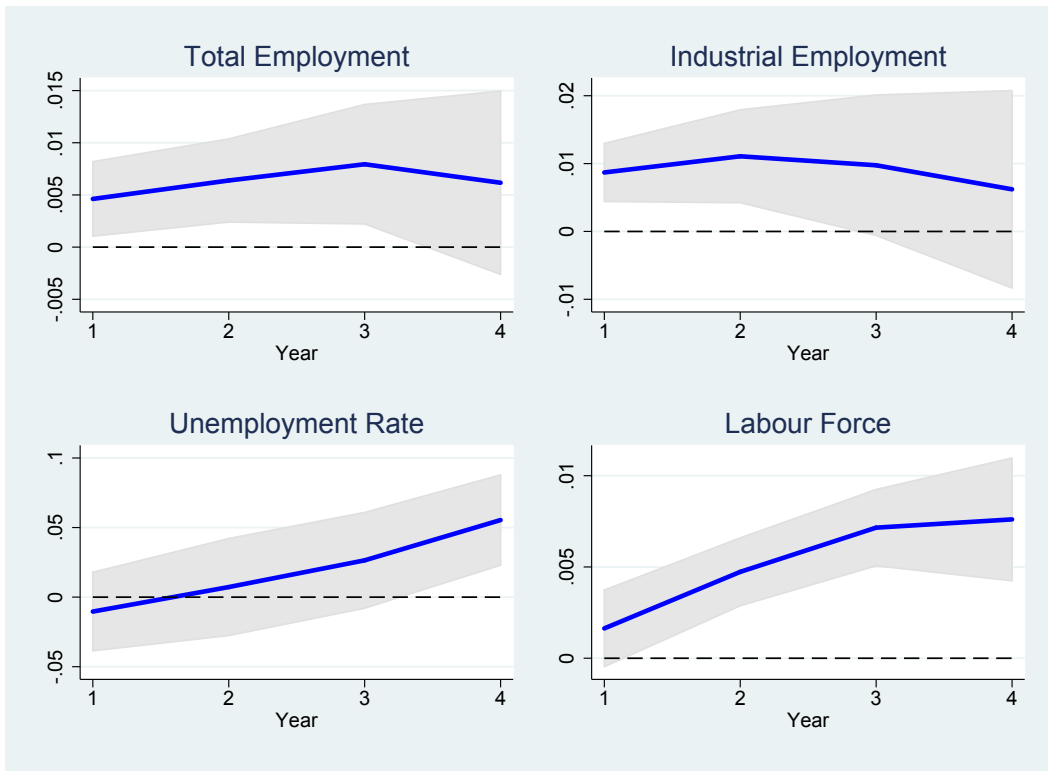


FIGURE 8. Spillovers to Irish sources of financing



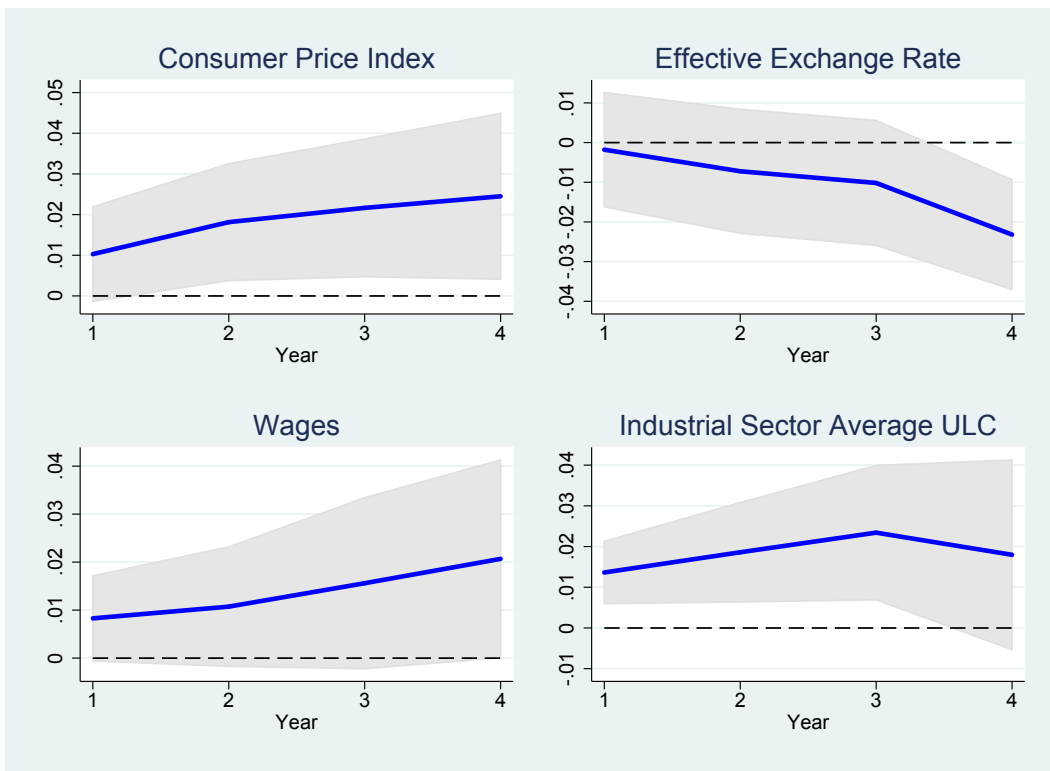
Notes: The solid lines represent the estimated impulse responses following a 1-percentage point decrease in the U.S. corporate income tax rate. The shaded areas contain the 90 percent confidence intervals.

FIGURE 9. Spillovers to Irish employment



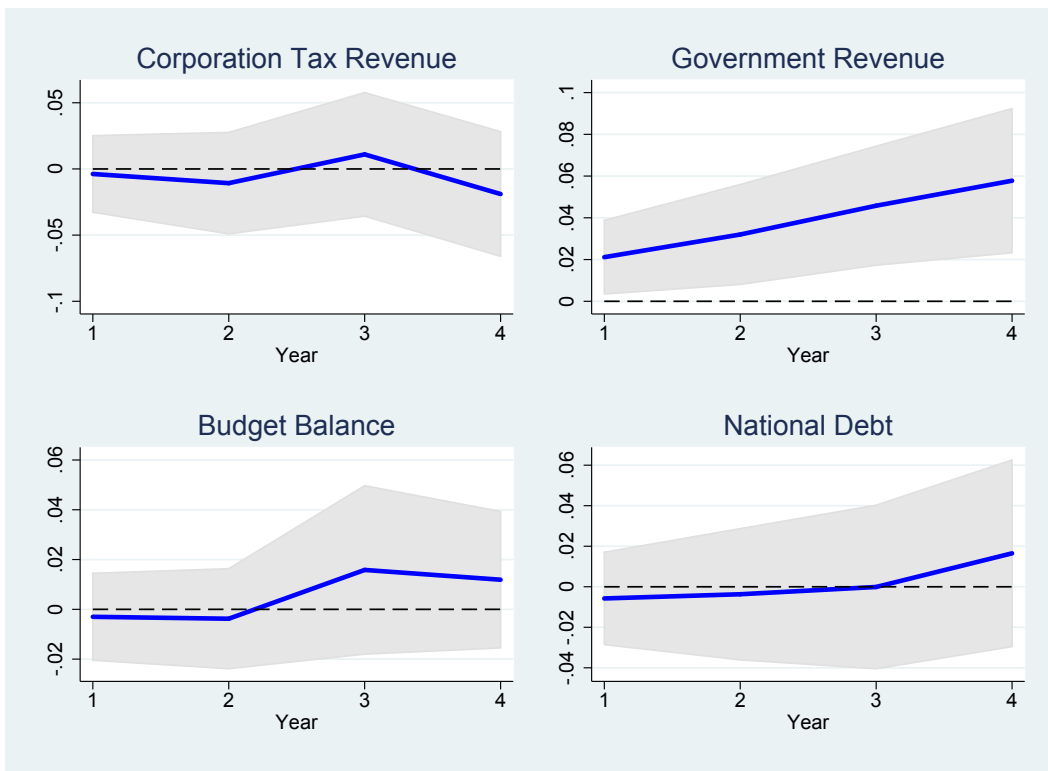
Notes: The solid lines represent the estimated impulse responses following a 1-percentage point decrease in the U.S. corporate income tax rate. The shaded areas contain the 90 percent confidence intervals.

FIGURE 10. Spillovers to Irish competitiveness



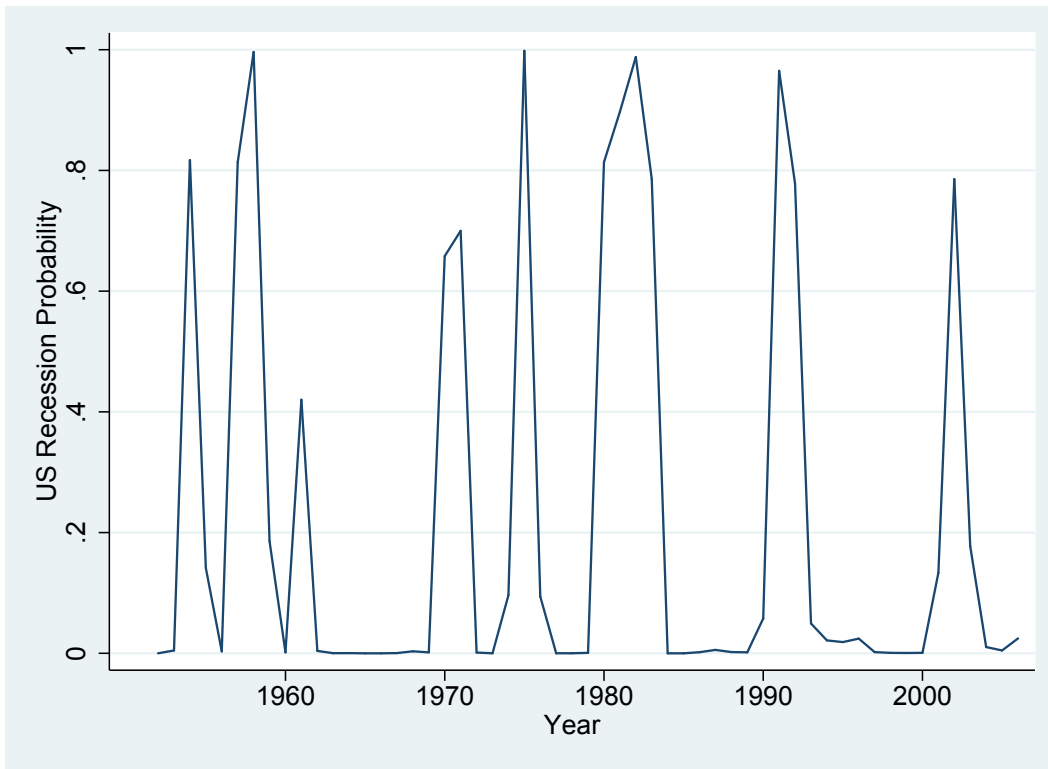
Notes: The solid lines represent the estimated impulse responses following a 1-percentage point decrease in the U.S. corporate income tax rate. The shaded areas contain the 90 percent confidence intervals.

FIGURE 11. Spillovers to Irish public finances



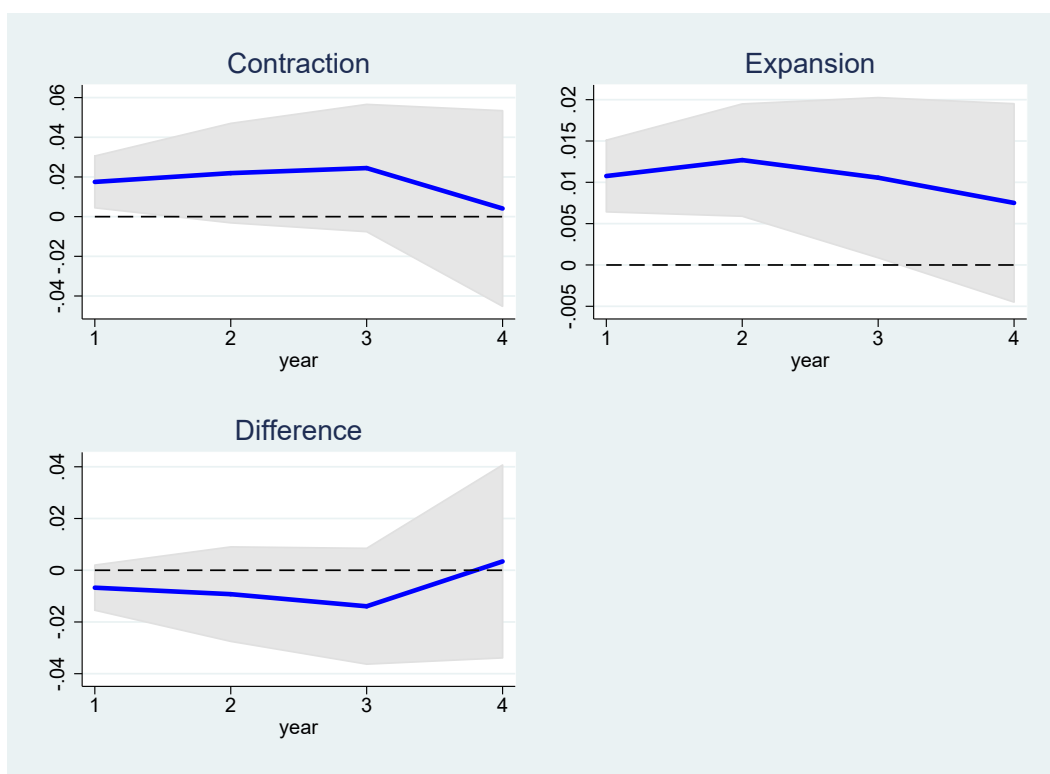
Notes: The solid lines represent the estimated impulse responses following a 1-percentage point decrease in the U.S. corporate income tax rate. The shaded areas contain the 90 percent confidence intervals.

FIGURE 12. State of the US business cycle



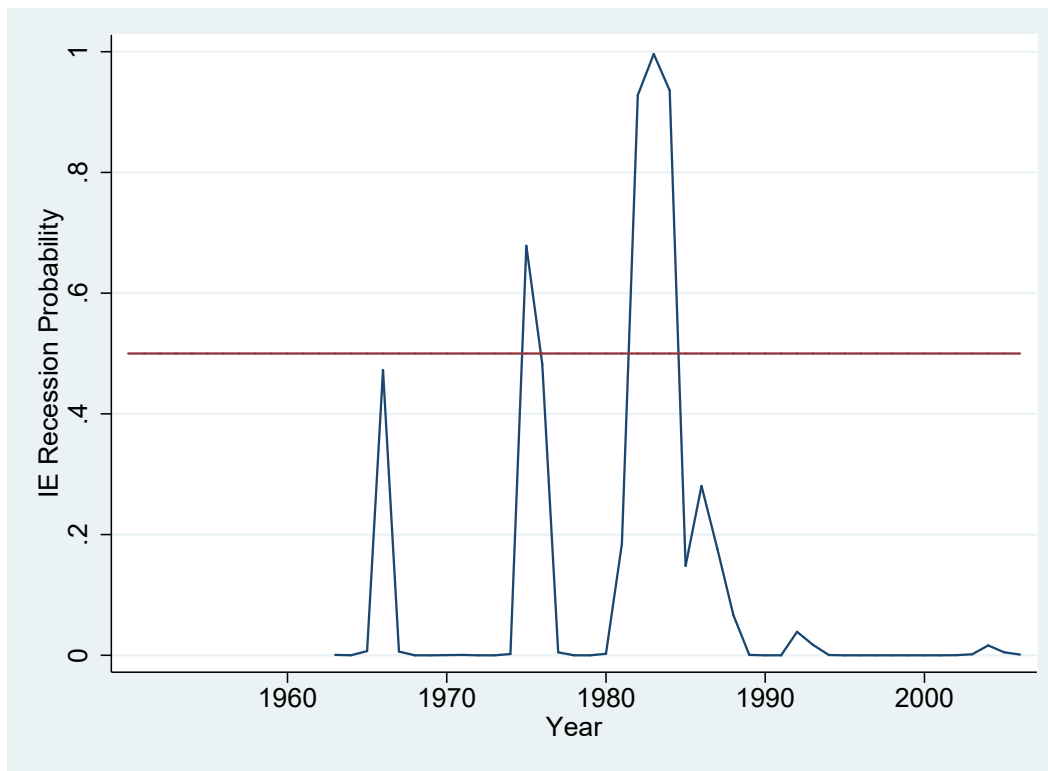
Notes: We derive the US state indicator variable following Auerbach and Gorodnichenko (2012)'s smooth transition probability approach. We then transform this continuous indicator into a dummy variable, that takes a value of one when the probability of being in a recession is greater than 0.5, for use in the state-dependent regressions. See Section 6.2 for details.

FIGURE 13. US state-dependent spillovers: Irish output



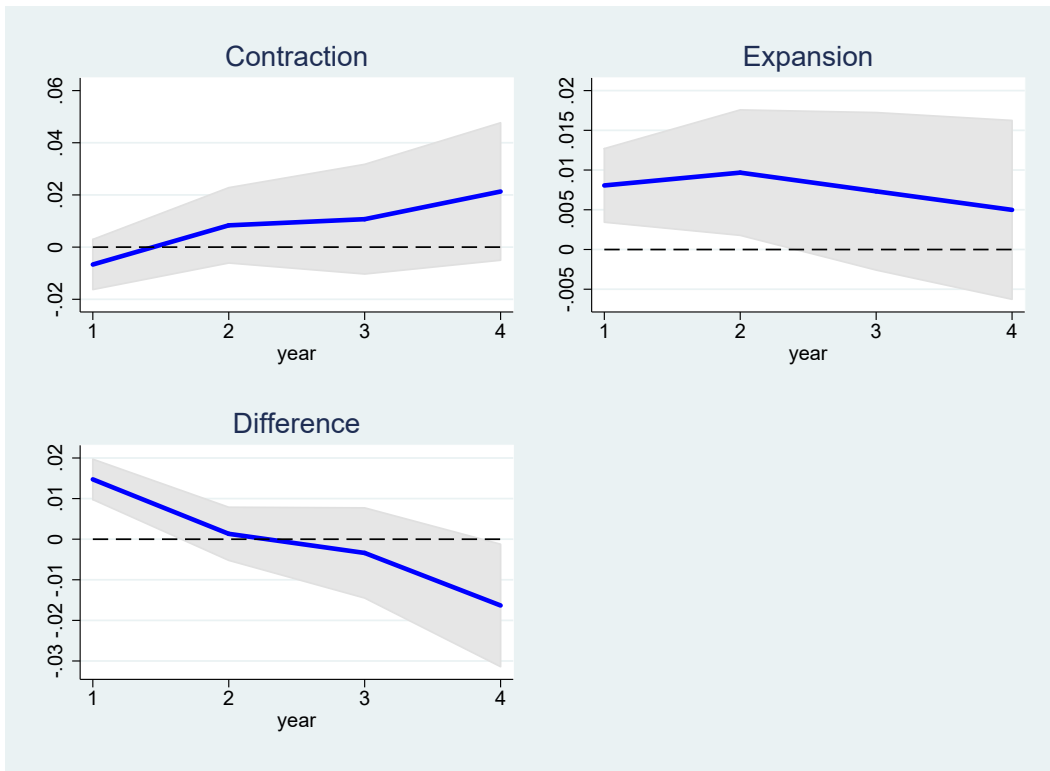
*Notes:* The solid lines represent the estimated impulse responses of Irish GDP following a 1-percentage point decrease in the U.S. corporate income tax rate. The shaded areas contain the 90 percent confidence intervals. The top-left panel shows the responses to a US corporate tax shock that occurs when the US economy has a higher probability of being in a recession. The top-right panel contains the responses to a US corporate tax shock that occurs when the US economy has a higher probability of being in an expansion. The bottom-left panel displays the difference in responses between the expansionary and recessionary states.

FIGURE 14. State of the Irish business cycle



Notes: We derive the Irish state indicator variable following Auerbach and Gorodnichenko (2012)'s smooth transition probability approach. We then transform this continuous indicator into a dummy variable, that takes a value of one when the probability of being in a recession is greater than 0.5, for use in the state-dependent regressions. See Section 6.2 for details.

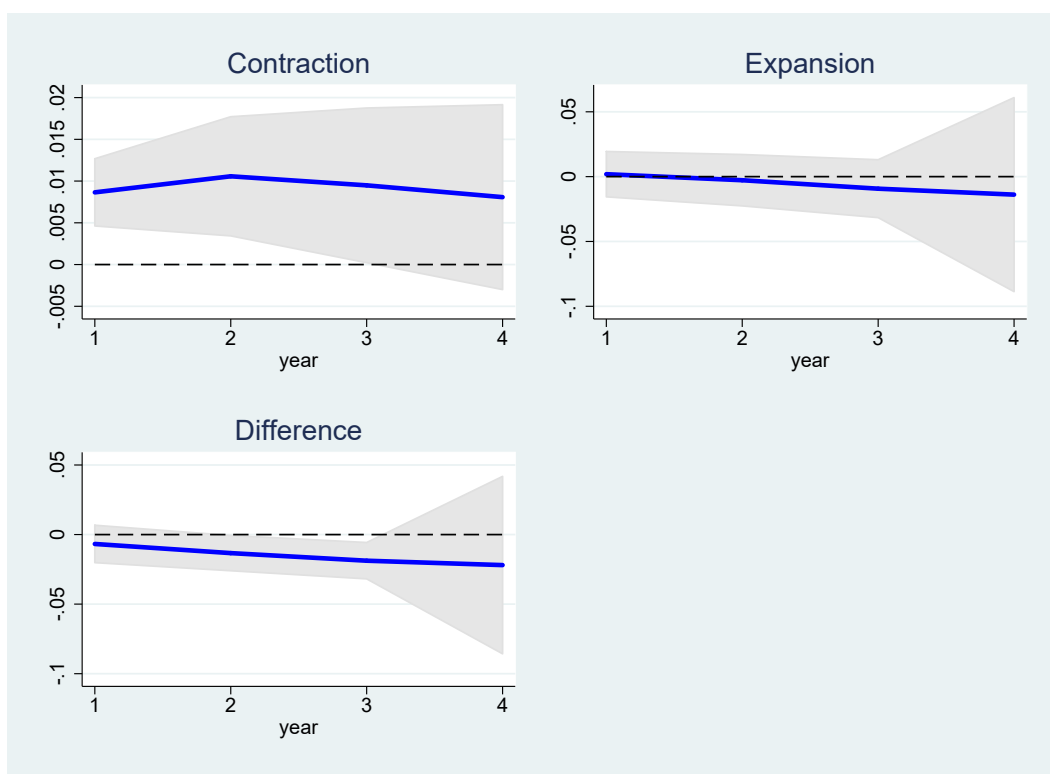
FIGURE 15. Irish state-dependent spillovers: Irish output



Notes: The solid lines represent the estimated impulse responses of Irish GDP following a 1-percentage point decrease in the U.S. corporate income tax rate. The shaded areas contain the 90 percent confidence intervals. The top-left panel shows the responses to a US corporate tax shock that occurs when the Irish economy has a higher probability of being in a recession. The top-right panel contains the responses to a US corporate tax shock that occurs when the Irish economy has a higher probability of being in a expansion. The bottom-left panel displays the difference in responses between the expansionary and recessionary states.

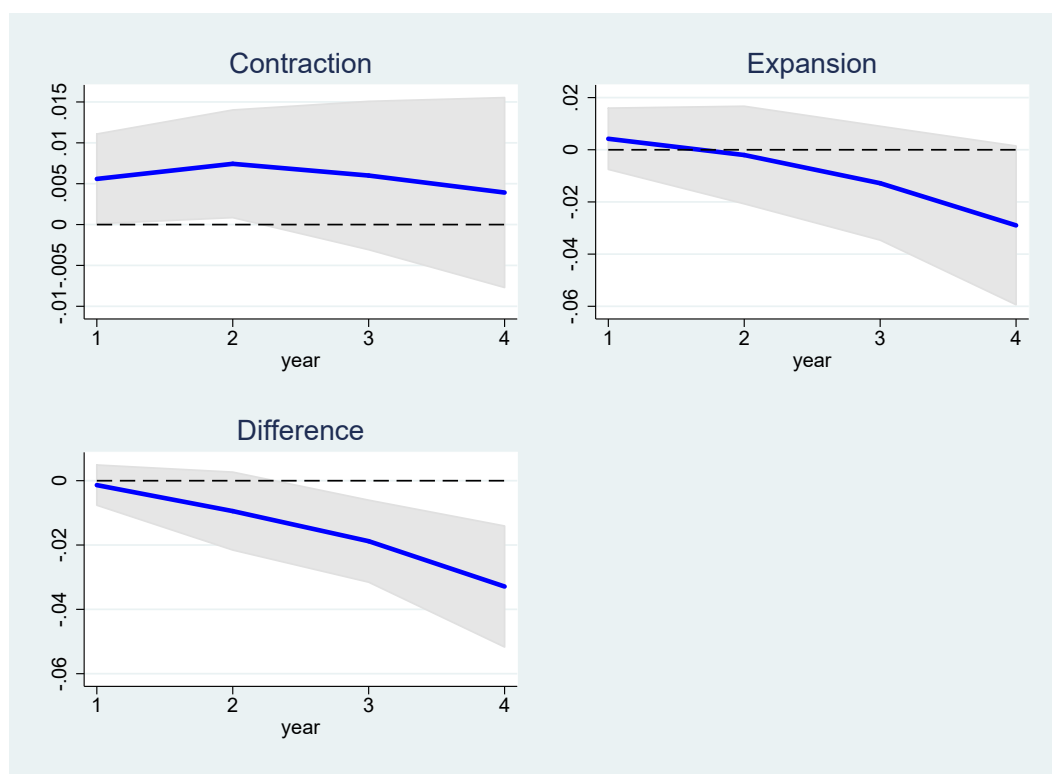


FIGURE 16. Irish employment-dependent spillovers: Irish output



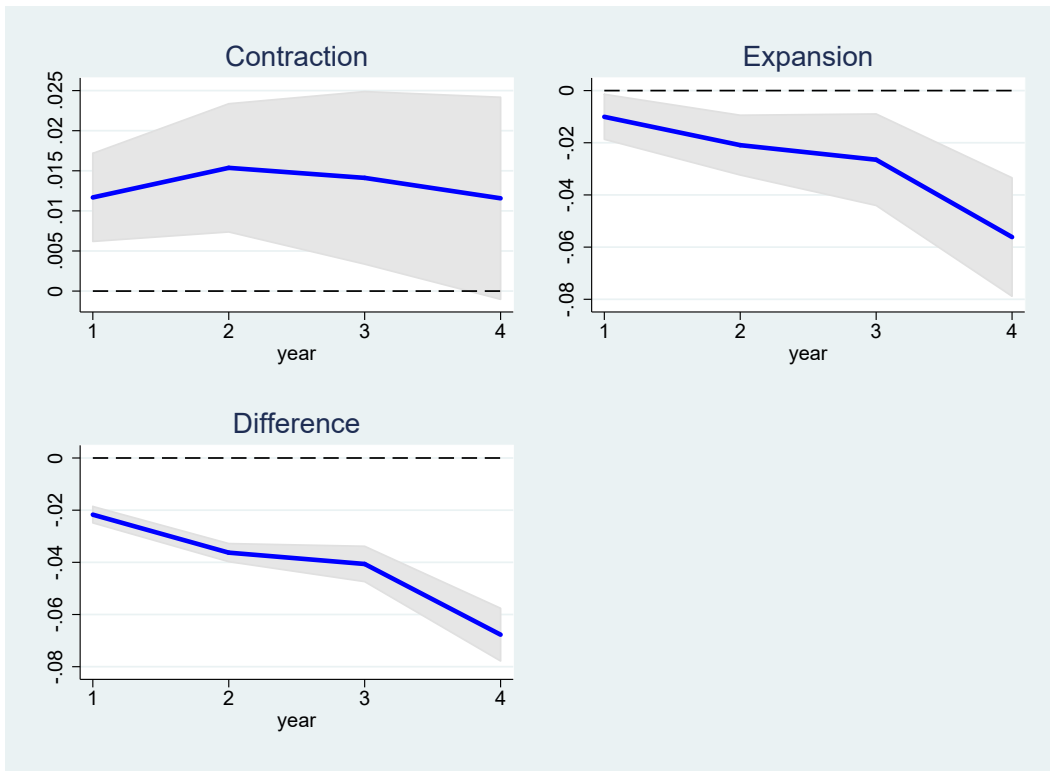
Notes: The solid lines represent the estimated impulse responses of Irish GDP following a 1-percentage point decrease in the U.S. corporate income tax rate. The shaded areas contain the 90 percent confidence intervals. The top-left panel shows the responses to a US corporate tax shock that occurs when the Irish economy has a higher probability of being in a period of below-average employment growth. The top-right panel contains the responses to a US corporate tax shock that occurs when the Irish economy has a higher probability of being in a period of above average employment growth. The bottom-left panel displays the difference in responses between the tight and slack employment states.

FIGURE 17. Irish unemployment-dependent spillovers: Irish output



*Notes:* The solid lines represent the estimated impulse responses of Irish GDP following a 1-percentage point decrease in the U.S. corporate income tax rate. The shaded areas contain the 90 percent confidence intervals. The top-left panel shows the responses to a US corporate tax shock that occurs when the Irish economy has a higher probability of being in a period with an above-average unemployment rate. The top-right panel contains the responses to a US corporate tax shock that occurs when the Irish economy has a higher probability of being in a period with a below-average unemployment rate. The bottom-left panel displays the difference in responses between the tight and slack unemployment states.

FIGURE 18. Irish migration-dependent spillovers: Irish output



Notes: The solid lines represent the estimated impulse responses of Irish GDP following a 1-percentage point decrease in the U.S. corporate income tax rate. The shaded areas contain the 90 percent confidence intervals. The top-left panel shows the responses to a US corporate tax shock that occurs when the Irish economy has a higher probability of being in a period with above-average net migration. The top-right panel contains the responses to a US corporate tax shock that occurs when the Irish economy has a higher probability of being in a period with below-average net migration. The bottom-left panel displays the difference in responses between the tight and slack migration states.

## Appendix A Irish-US interdependencies

Given the need for at least some judgement in the construction of the narrative shock series, Mertens and Ravn (2013, 2014) allow for correlation between their narrative measures with latent tax shocks. Their proxy structural vector autoregression (proxy SVAR) model provides a new approach for identifying shocks using external instruments (Ramey 2016). This allows them to ascertain exactly how exogenous their narrative shocks are, facilitating an assessment of their reliability. They estimate the dynamic effects of unanticipated US corporate income tax shocks using a seven-variable proxy SVAR:

$$Y_t = B(L)Y_t + \Omega\epsilon_t, \quad (4)$$

where  $B(L)$  represents a polynomial in the lag operator and  $Y_{i,t}$  is a vector containing: (i) average US personal income tax rates; (ii) average US corporate income tax rates; (iii) US personal income tax base; (iv) US corporate income tax base; (v) US federal government purchases of final goods and services; (vi) US GDP; and (vii) US federal government debt. All variables, except the tax rates, are expressed in real per-capita terms. The model also includes two lags of the endogenous variables. By using narratively identified shocks with a proxy SVAR framework, this estimation strategy exploits the attractive features of both approaches to modelling the dynamic response of the economy to fiscal shocks.

We instead use the local projections approach to estimate the dynamic response of the Irish economy to US corporate income tax cuts. This is because of the greater flexibility provided by local projections, which permits us to conduct a more detailed analysis of the transmission channels and state dependencies of the spillover effects. To ensure that there are no feedbacks between the Irish economy and the dynamic effects of US corporate income tax shocks on the US economy, we check for the presence of such independencies. These would necessitate the modelling of the dynamic response of the Irish economy to US corporate tax shocks as a system of equations (rather than

the single equation approach used in local projections).<sup>21</sup> We supplement the model by adding Irish (real per-capita) GDP as an endogenous variables (i.e. we include it in the  $Y_t$  vector in Eqs. 4) and using annual rather than quarterly data.<sup>22</sup> We order this variable last and assume it does not affect any of the US variables contemporaneously.

Table 3 shows the results on US output from a shock to US corporate income tax rates with and without Irish GDP included in the model specification. There is very little difference in the estimated US output response, and the overlapping standard error bands demonstrate that there is no statistical difference between these estimates. This lack of interdependence allows us to use the single-equation local projections approach to model the dynamic response of the Irish economy to US corporate income tax cuts.

TABLE 3. Irish-US interdependencies

	Year 1	Year 2	Year 3	Year 4
<b>US-only proxy SVAR</b>				
Estimated US output response	0.380	0.617	0.702	0.602
Upper (90%) confidence interval	0.753	0.972	1.038	0.828
Lower (90%) confidence interval	0.140	0.236	0.253	0.118
<b>Proxy SVAR with Irish GDP</b>				
Estimated US output response	0.346	0.620	0.652	0.518
Upper (90%) confidence interval	0.764	1.035	0.980	0.727
Lower (90%) confidence interval	0.049	0.209	0.175	0.433

Notes: US output responses to a US corporate income tax shock, estimated using a proxy SVAR with and without Irish GDP included as a variable.

<sup>21</sup>O’Grady et al. (2017) provide evidence supporting the weak exogeneity of foreign variables with respect to their domestic counterparts using a Global VAR approach. They note that by conditioning country-specific models on weakly exogenous foreign variables, residual interdependencies are stripped of correlates resulting from “common” global factors. The remaining interdependencies would more likely account for spillover effects due to economic policy and trade.

<sup>22</sup>Figure 2 demonstrates that this change in data frequency does not alter the results in Mertens and Ravn (2013). We also adopt Mertens and Ravn (2013)’s approach of dropping variables related to the other tax shock when using annual data. They do this to preserve degrees of freedom. Therefore, we estimate a six-variable proxy VAR, dropping US personal income tax rates and the US personal income tax base while adding Irish GDP to the model specification.

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