Taxation, Expenditures and the Irish Miracle*

Paul Klein
Stockholm University

Gustavo Ventura
Arizona State University

March 15, 2018

Abstract

We examine the role of fiscal policy in accounting for the remarkable rise of Ireland from one of Western Europe's poorest countries to one of its richest in just a few years. We focus on the importance of business tax reform and changes in the size of government, in conjunction with other factors, which we model as a residual rise in Total Factor Productivity (TFP). We conduct our analysis using a two-sector, small-open economy model where production requires tangible and intangible capital services, and where inflows of capital are limited by a collateral constraint. We find that the much discussed reductions of business taxes played a significant, but secondary, role in the Irish miracle. However, tax reform and other changes strongly reinforce each other. We also find that Ireland's openness to capital movements was crucial: under the same driving forces, a closed economy would have experienced a much slower and significantly smaller rise in GDP.

Keywords: Ireland; Corporate Taxation; Fiscal Policy; Economic Development.

JEL Classification: O4, H2, F2.

*We thank conference participants at the Vienna Macro Café, Canadian Macro Study Group, II MadMac Conference in Growth and Development, as well as seminar participants at the Central Bank of Chile, Concordia University, Sveriges Riksbank, Oslo Macro Group (OMG) and Universidad de Chile. Special thanks to Georg Duernecker and Paul Gomme for useful comments and suggestions.
Affiliations: Paul Klein, Dept. of Economics, Stockholm University. Email: paul.klein@ne.su.se. Gustavo Ventura, Dept. of Economics, Arizona State University. Email: gustavo.ventura@asu.edu.

1 Introduction

In 1980, Ireland's output per adult was about 49% of the United States level in PPP terms. By 2005, Ireland was among the richest countries in the world, with a level of output per adult even higher than that of the United States (about 105%). Employment increased substantially in the same period. The employment rate went from 59 to 69 percent of the adult population, though hours per worker went down, leaving total hours worked per adult about the same in 2005 as they were in 1980.[1] This is a phenomenal performance that has not been sufficiently investigated in the macroeconomic literature. We refer to it as the *Irish miracle*.

In this paper, we assess the quantitative significance of policy-driven factors that may have led to the Irish miracle. In particular, we concentrate on two key factors: gradually falling corporate taxes and a fall in government consumption and transfers relative to output. We analyze these factors in isolation and in conjunction with a residual rise in Total Factor Productivity (TFP). We ask: what is the quantitative importance of the drastic changes in business taxation in Ireland? What is the role of an 'austere' Irish policy in regard to government expenditures? How do these changes interplay with each other in the context of an economy open to capital flows?

Drastic changes in business taxation were concomitant to the performance of the output performance of Ireland. In the 1980s, a process of a large but gradual reduction of tax rates on business income began. The process started from a rate of 50% on non-manufacturing business income, to the rate of 12.5% that was achieved in 2003 and continues until nowadays. In addition, the special tax treatment of the manufacturing sector was changed, and by 2003 all sectors were taxed at the same rate. As it has been much discussed in popular debates, the current rate of 12.5% is the lowest among OECD countries. Figure 1 exhibits these large changes alongside the changes in Irish GDP per adult. In similar fashion, other

[1] We focus on "per adult" statistics since Ireland went through a very noticeable demographic transition during the period we are interested in, resulting in a larger fraction of people aged 15-64 in the population. Indeed, that fraction too went up from 59 to 69 percent.

changes in fiscal policy took place, with the size of the government sector changing non-trivially as a share of output. While government transfers remained relatively constant at 9% of GDP, government consumption fell as a share of output by about six percentage points; from about 20% in 1980 to 14% in 2005. In this context, as the Irish economy took off, substantial foreign capital flowed in and a gap opened up between GDP and GNP that increased over time. While in 1980, GNP was about 97 percent of Ireland's GDP, the corresponding figure in 2005 was about 86 percent.[2] This is a large gap by any empirical standard.

Clearly, given the emerging gap between GDP and GNP, it would be inappropriate to analyze the Irish experience through the lens of a closed-economy model. Hence, we conduct our analysis in the context of a small-open economy. In our model economy, a representative household enjoys a final consumption good and dislikes work. The final consumption and investment good is produced via the aggregation of two intermediate goods produced in different sectors, m and s. Production of each of these goods requires labor as well as services of standard or *tangible* capital, as well as *intangible* capital services. Motivated by the Irish experience, the two intermediate goods differ in terms of their tax treatment; the sector-specific business tax rates follow distinct paths over time. In sector m (manufacturing), tax rates are initially low and essentially unchanged over time. In the s sector (services or, rather, everything but manufacturing), tax rates are initially high and subsequently drop gradually. The government in this economy also taxes labor income and issues government debt, consumes and provides transfers to the representative household.

A well-known feature of small-open economy models without frictions is that there is no gradual transition but instead abrupt jumps between steady states in response to changes in policy or productivity. This is not only theoretically awkward, but implies a counterfactually large gap between GDP and GNP that opens up immediately. As we mentioned earlier, the gap between GNP and GDP in Ireland increased gradually over time and eventually became substantial. It is

[2]Source: National Income and Expenditure, various years, Central Statistical Office, Ireland.

not, however, large by the theoretical standard given by a frictionless small-open-economy model. To address this issue, we employ a variant of the approach of Barro et al. (1995) by assuming that each household faces a collateral constraint when borrowing from abroad. In Barro et al. (1995), physical but not human capital could be used as collateral; in our model, it is government bonds and intangible capital that cannot be used as collateral, but a fraction (possibly greater than one) of physical capital can be so used. This leads quite naturally to a protracted adjustment in response to a tax reform, to changes in the size of the government or to a rise in TFP.

We note that conducting our analysis in an open-economy context is important for our findings. For instance, a closed economy responds quite differently in the long run to a an exogenous change in TFP. Specifically, if preferences belong to the King et al. (1988) class, then long-run labor supply does not respond at all to such changes when the economy is closed. When it is open, however, it does, because a part of the wealth effect is then removed as a result of foreigners owning part of the capital stock.

We calibrate our model economy to reproduce the conditions of the Irish economy circa 1980, including values for the tax rates on corporate income by sector as well as government consumption and transfers. We then force the model to reproduce the key aspects of the transition of Irish economy from 1980 to 2005. Specifically, (i) we impose the observed sequences of tax rates by sector as well as government consumption and transfer payments as a fraction of output; (ii) we force the model to reproduce the GNP to GDP ratio; (iii) we force the model to reproduce the time path of output per adult (relative to a two percent trend). In doing so, we infer the increase in residual increase TFP and the importance of the collateral constraint. We find that our model can match the observed output changes, relative to trend, very well. We also find that the model can naturally generate the gradually growing gap between GDP and GNP for Ireland in the period 1980-2005, providing in this way a key discipline to our quantitative exercises.

Our findings are the following. First, we find that the much discussed changes in corporate taxation in Ireland played a significant, but nevertheless secondary role in the Irish miracle. We find that if changes in tax rates had been the *only* factor changing in the period, Ireland output would have increased by only 26% relative to trend—less than a fourth of the observed change of 112%. Second, we find that the entire package of fiscal policy changes has more significant consequences. Changes in business taxes, government consumption and transfers lead to changes in output of about 36% relative to trend. Third, we find that given exogenous changes in taxation and the size of the government, only modest increases in TFP are needed in order to generate the observed changes in GDP. Our findings imply TFP increases of only about 20% between 1980 and 2005. Nevertheless, we find that the inferred changes in TFP were a dominant force in the Irish context. We find that these changes in isolation would have led to a hypothetical increase in output per adult of more than half of the observed increase—about 62%. Finally, we find that modeling Ireland as a small-open economy is critical in this context. We find that the same driving forces would, by 2005, have led to an increase in output per adult relative to trend of less than half of the changes observed.

Related Work Our work can be thought of as a contribution to the large and growing literature that uses a version of the growth model in order to better understand historical episodes, and, in particular, to examine the significance of fiscal policy. An early prominent contribution to this literature is Crucini and Kahn (1996)—later followed up by Crucini and Kahn (2003)—who use a growth model to measure the quantitative importance of tariffs for the Great Depression. Ohanian (1997) studied the role of war financing (contrasting World War II with Korea) in the United States, while McGrattan and Ohanian (2010) compared the predictions of the growth model for war financing in World War II with data. Similarly, Cooley and Ohanian (1997) studied the role of capital income taxes in accounting for the postwar stagnation of the United Kingdom. McGrattan (2012) revisited and revised the conclusion of Cole and Ohanian (1999) that fiscal policy

was not important for the U.S. Great Depression.

Our work can also be thought of as a contribution to a small literature trying to make sense of Ireland's recent economic history. Honohan and Walsh (2002) provide a compelling narrative account of Ireland's rise, emphasizing the importance of fiscal policy reform. Ahearne et al. (2006) study Ireland's stagnation from 1973 to 1985, i.e. the pre-reform era. The purpose of Barry and Devereux (2006) is closer to ours: to use theory to assess the relative significance of various factors in accounting for Ireland's more recent rise. However, their emphasis is quite different from ours. In particular, they examine the importance for Ireland of having a common labor market with the rest of the EU, and argue that the influx of labor from abroad during the 1990's made a significant difference for the growth in GDP. By contrast, we focus in the present paper on output *per adult*, not on total output, and take demographic changes as given. In this rather obvious sense, our work is complementary to theirs.

Our analysis proceeds as follows. In Section 2, we document in detail the changes in the Irish economy in the period 1980-2005. In Section 4, we assign parameter values to our model. In Section 5, we analyze the quantitative implications of changes in taxation, expenditures and residual TFP for the Irish economy. In Section 6, we put our main findings in perspective via additional calculations and counterfactuals. Finally, in Section 7, we provide concluding remarks and avenues for future research.

2 Ireland 1980-2005: Key Facts

We summarize below a set of facts that document the spectacular rise of Ireland in the period 1980-2005. Likewise, as a comparison, we present corresponding statistics for Spain—a European country at similar stage of development around 1980—to highlight the similarities and the uniqueness of the Irish economy in this period. Unless specified otherwise, all data that we use are measured at internationally comparable prices and come from the Penn World Tables 8.1.

The Output Miracle To provide an account of the Irish development miracle, we focus on output per working-age adult (ages 15-64), or *per adult* for short, to minimize the effects of demographic swings.[3] From 1980 to 2005, Ireland's GDP per adult increased by a factor of nearly 3.5, at an average annual rate of about 5.1 percent. Nothing approaching this impressive growth rate was experienced by any of the member countries of the European Union that joined before 2000. Indeed, even among those who joined later, only Poland's experience is comparable. In relative terms, Ireland went from about 49 percent of that of the United States to about 105 percent. Here, it is worth noting that prior to 1980, Ireland was relatively stable relative to the United States. For instance, in 1975, Ireland's GDP per adult was 43 percent of that in the United States. Figure 2 below illustrates this fact. What we can see there is that though Ireland's growth was high from 1980 onwards, there was a marked acceleration starting in 1992-93. From 1992 to 2005, GDP per adult grew at an average annual rate of 6.9 percent.

It is worth noticing that, in per capita terms, Ireland's growth was even more spectacular. Between 1980 and 2005, GDP per capita grew at an average annual rate of 5.7 percent as the adult share of the population increased; see below.

GNP versus GDP Much of measured output's rise in Ireland was fueled by foreign investment. As a result, a gap opened up between GDP and GNP, with a gradually shrinking GNP/GDP ratio. This ratio declined by about 12 percentage points in the period 1980-2005; it went from about 97 percent to about 85 percent. Figure 3 below illustrates the path of the GDP/GNP ratio in Ireland.

Hours Worked and Demographics The dramatic changes in output documented above were accompanied by large changes in employment and hours of work. The employment rate increased from 1980 to 2005, from about 59 percent to 69

[3] To compute statistics in per-adult terms, we use population figures for ages 15-64 as reported by the OECD.

percent.[4] The effect of this rise in employment on hours was mitigated by a fall in hours per employee, that fell substantially, by about 14.7 percent in the period. Overall, total hours worked per adult fell from 1980 to 1985, stagnated between 1985 and 1992 and then increased from 1992 to 2005 to return roughly to where they were in 1980. It is worth noting that the initial drop in hours per adult was substantial, with a trough being about 15 percent below the two peaks.

The observed changes in hours worked were concomitant with non-trivial demographic changes. While total population grew at a modest pace in the period 1980-2005 at about 0.8 percent per annum, the adult population grew more substantially, with an annual increase of about 1.4 percent in the period—a factor of about 1.4 over 25 years.

Government Spending Government spending (consumption plus transfers) fell as a fraction of GDP during the period 1980-2005, from about 29 to about 24 percent. Essentially all of that reduction came from government purchases, whose share of GDP fell from 20 percent to 14 percent. Transfers remained roughly constant as a share of output. As a fraction of GNP, however, Irish government spending appears less austere: government consumption fell only by about 4 percentage points of GNP while government transfers went up, from about 9 percent in 1980 to 11 percent in 2005. Table 1 presents the evolution of government consumption and transfer shares in the period 1980-2005.

Tax Rates Statutory tax rates on business income fell significantly in the period 1985-2005. We refer to these rates—as others do—as 'corporate' income tax rates. In 1985, Ireland had a statutory tax rate that at 50 percent was comparable to those of other West European countries, even when the manufacturing sector enjoyed a much lower effective corporate tax rate than the statutory one. In the 1990s, a process of reduction and harmonization took place. By 1995, the statutory corporate income tax rate had been reduced significantly and was already competitive

[4]We define the employment rate in the standard way: number of individuals employed as a fraction of the population 15-64 years old in a given year.

at a 38 percent rate. The reduction continued apace, with the statutory rate falling to 24 percent in 2000, 20 percent in 2001, 16 percent in 2002 and, finally, 12.5 percent in 2003. The rate has not changed after that. Figure 4 below illustrates the pattern of statutory rates in this period. This pattern contrasts sharply with that of the United States and OECD countries, as the figure illustrates.[5]

Educational Attainment There were some changes in the educational attainment of the Irish workforce in the period 1985-2005. From Barro and Lee (2010) we calculate that average years of schooling went from around 9.9 in 1980 to about 11.9 years in 2005. It is worth noticing that changes in other countries (e.g. Spain) were noticeably larger; see below.

2.1 Comparison with Spain

We describe here some similarities and differences between Ireland and Spain. This serves to illustrate and highlight how extreme the Irish experience was relative to a similarly situated country at a similar level of development around 1980. This also helps to justify our model choices that focus on policy differences and residual changes in productivity as the main proximate causes of Ireland's rise.

1. Spain experienced nothing like Ireland's growth spurt. While Spain and Ireland were quite similar during the eighties, their paths diverged considerably afterwards. In 1980, Ireland had a level of output per adult about 4.5 percent *lower* than Spain's, while the level of output per worker was about 15 percent lower. In 1995, Ireland's output per adult was about 27 percent higher than Spain's. Ten years later, Ireland's output per adult was about 75 percent higher than Spain's.

2. The capital inflows from abroad that Ireland experienced had no Spanish counterpart, and Spanish GDP was approximately equal to GNP throughout the period.

[5]Source: http://taxfoundation.org/article/oecd-corporate-income-tax-rates-1981-2013.

3. Both Ireland and Spain underwent similar processes of structural transformation. Around 1985, agriculture accounted for about 15 percent of employment in both Spain and Ireland. By 2005, that number had fallen to about 5 percent in both countries.

4. Both countries experienced large demographic transitions between 1980 and 2005. As noted earlier, the share of adults 15-64 years old in the population went from about 58.9 percent to 68.9 percent. In Spain, the demographic shift was somewhat stronger; the adult share increased from 52.5 percent in 1980 to about 63.7 percent in 2005.

5. The educational attainment of the workforce increased in both countries, albeit at different rates. As we noted earlier, in Ireland average years of schooling went from around 9.9 in 1980 to about 11.9 years in 2005, or by about two years. In Spain, the increase was much stronger. Average years of schooling increased by more than *five* years; they went from about 5.5 in 1980 to 10.8 in 2005.

From the summary above, it seems far-fetched to attribute the differential performance of Spain and Ireland to either demographic factors, different speed of structural transformation or to a rapid increases in the schooling attainment of the workforce. Indeed, given the similarities between the countries in these respects, a development miracle probably had somewhat better odds in Spain than in Ireland.

3 The Model

We describe below the model economy that we use in our quantitative exercises. We first provide some background for our modeling choices, and subsequently describe the model in detail.

A two-sector economy with two types of capital The model features two sectors, a manufacturing sector and a non-manufacturing (or service) sector. These sectors produce imperfectly substitutable goods that are combined to produce the final good. This final good serves multiple purposes as a consumption good, a tangible investment good and an intangible investment good.

The distinction between manufacturing and services is there to enable us to reproduce the fact that in Ireland, from the early 1980s until 2003, manufacturing was treated more leniently than other sectors when it came to corporate taxation.

The presence of intangible capital in production is motivated by the work of Corrado et al. (2006), Hall (2001), McGrattan and Prescott (2010) and McGrattan and Prescott (2017), among many others, who have documented the empirical relevance of intangible capital and demonstrated its importance in accounting for macroeconomic phenomena. It is especially relevant for our analysis, since as documented above, the Irish miracle was to a large extent driven by large flows of investment from abroad. Given the large extent to which these inflows were associated with the pharmaceutical and IT sectors,[6] it is not hard to believe that they were accompanied by the arrival of blueprints, brands, developed production methods, etc., that are valuable in the production process. For our purposes, the importance of incorporating intangible capital into our model is that it provides an empirically plausible amplification mechanism—its presence tends in the direction of attributing larger significance to business tax reform and government spending (purchases and transfers) reform, leaving relatively less for changes in residual TFP to account for. An incidental consequence of introducing intangible capital into the model is that it permits us to endogenize measured TFP; even in the absence of any increase in (exogenous) TFP, the model implies a sizeable increase in measured TFP.

The collateral constraint To avoid instantaneous transitions from one balanced growth path to another, and, more importantly, to avoid counterfactually large

[6] See for instance Central Statistics Office (2011).

gaps between GDP and GNP, we introduce a friction affecting international capital flows. The approach follows that of Barro et al. (1995). Specifically, international borrowing has to be backed by collateral, which is a given fraction (possibly greater than one) of tangible capital; intangible capital (or government bonds) cannot be used as collateral at all. This implies that, along a transition path, rates of return may differ across different assets, with domestic government bonds and intangible capital earning the highest rate of return, foreign bonds the lowest, and tangible capital lying somewhere in the middle.

3.1 Details

A representative household has preferences over consumption (c) and hours worked (h) given by

$$\sum_{t=0}^{\infty} \beta^t u(c_t, h_t) \tag{1}$$

where

$$u(c, h) = \ln c - \frac{\psi}{1 + 1/\varepsilon} h^{1+1/\varepsilon}$$

where $\psi > 0$ and $\varepsilon > 0$. The parameter ε is the (constant) Frisch elasticity of labor supply. The household faces the constraint

$$c_t + a_{t+1} + q_t b_{t+1} + k_{t+1} + z_{t+1} = \widehat{w}_t h_t + \widehat{R}^k_t k_t + \widehat{R}^z_t z_t + R^a a_t + b_t + \mathcal{T}_t. \tag{2}$$

The variable a_t stands for holdings of foreign bonds, b_t is holdings of domestic government bonds, k_t is holdings of tangible capital and z_t is holdings of intangible capital. Also, R^k_t is the pre-tax rate of return on physical capital, q_t is the price of government bonds, and R^a is the (constant) world interest rate and R^z_t is the pre-tax rate of return on intangible capital. Hats over rates of return indicate that the corresponding rates are after tax. Notice that bond returns are *not* taxed; only labor, intangible and physical capital returns are subject to taxation.

(This is mainly a matter of notational convention rather than substance.) $\mathcal{T}_t$ is a lump-sum transfer payment.

The representative household is also subject to the following collateral constraint:

$$a_{t+1} + \varphi k_{t+1} \geq 0. \tag{3}$$

The constraint states that a fraction φ of physical capital can be used as collateral; no intangible capital can be used for that purpose. Nor can government bonds be used as collateral, reflecting the fact that it does not constitute net wealth. It follows that the representative household maximizes (1), subject to (2), (3) and $k_0 > 0$, $z_0 > 0$ and a_0 given.

In the absence of a collateral constraint, after-tax rates of return would equalize across all assets: foreign bonds, domestic government bonds, physical capital and intangible capital. In the presence of a collateral constraint, these returns only equalize in the long run but may differ in the short run; if the collateral constraint binds in any period, then those rates of return are distinct in that period, except for the rates of return on intangible capital and government bonds, which are always equal.

Production The final (consumption and investment) good is produced according to

$$Y_t = \bar{A}_t[\alpha_s Y_{s,t}^{\xi} + (1-\alpha_s)Y_{m,t}^{\xi}]^{1/\xi} \tag{4}$$

where $\bar{A}_t$ is exogenously given productivity (TFP), Y_s is the output of the s sector and Y_m is the output of the m sector and where $-\infty < \xi < 1$. $\xi \to 0$ corresponds to the Cobb-Douglas case.

Intermediate goods production requires three inputs under constant returns to scale: labor, tangible capital and intangible capital. Output in the m sector is

produced according to

$$Y_{m,t} = K_{m,t}^{\theta_k} Z_{m,t}^{\theta_z} H_{m,t}^{1-\theta_k-\theta_z} \tag{5}$$

and output in the s sector is produced according to

$$Y_{s,t} = K_{s,t}^{\theta_k} Z_{s,t}^{\theta_z} H_{s,t}^{1-\theta_k-\theta_z}. \tag{6}$$

Taxation Labor is taxed at a constant rate τ so that

$$\widehat{w}_t = (1-\tau) w_t$$

where w_t is the pre-tax wage. Income from physical capital in the s sector is taxed at a possibly time-varying rate $\tau_t^{k,s}$ and, similarly, income from physical capital in the m sector is taxed at a possibly time-varying rate $\tau_t^{k,m}$ so that

$$\widehat{R}_t^{k,s} = 1 + r_t^{k,s} - \delta_k - \tau_t^{k,s}(r_t^{k,s} - \delta_k)$$

and

$$\widehat{R}_t^{k,m} = 1 + r_t^{k,m} - \delta_k - \tau_t^{k,m}(r_t^{k,m} - \delta_k),$$

where $r_t^{k,s}$ and $r_t^{k,m}$ are the rental rates of physical capital in the s and m sectors, respectively, and δ_k is the depreciation rate of tangible capital.

Income from intangible capital is taxed according to the same principles—and at the same rates—as income from tangible capital. Thus

$$\widehat{R}_t^{z,s} = 1 + r_t^{z,s} - \delta_z - \tau_t^{k,s}(r_t^{z,s} - \delta_z)$$

and

$$\widehat{R}_t^{z,m} = 1 + r_t^{z,m} - \delta_z - \tau_t^{k,m}(r_t^{z,m} - \delta_z).$$

where δ_z is the depreciation rate of intangible capital.

Equilibrium In equilibrium, the aggregate uses of capital and labor must satisfy:

$$Z_t = Z_{m,t} + Z_{s,t};$$

$$K_t = K_{m,t} + K_{s,t};$$

and

$$H_t = H_{m,t} + H_{s,t}.$$

The flow budget constraint for the government is given by:

$$B_t + G_t + \mathcal{T}_t = \tau w_t H_t + \sum_{i\in\{m,s\}} \tau_t^{k,i}(r_t^{k,i} - \delta_k)K_{i,t} + \sum_{i\in\{m,s\}} \tau_t^{k,i}(r_t^{z,i} - \delta_z)Z_{i,t} + q_t B_{t+1} \tag{7}$$

with the limiting condition

$$\lim_{t\to\infty} \left(\prod_{k=0}^{t-1} q_k \right) B_t = 0 \tag{8}$$

where G_t stands for government consumption at date t, B_t is government debt inherited from period $t-1$ (or exogenously given in period 0) and q_t is the price of government bonds issued in period t. Notice that the first term on the right stands for tax collections out of labor income, whereas the second and third terms stand for revenues from taxes on tangible and intangible capital in both sectors.

We now state the various conditions that need to hold in a competitive equilibrium.

The rental rates of capital use in both intermediate sectors are equal to the values (in terms of the final good) of the corresponding marginal products of capital:

$$r_t^{k,s} = q_{s,t}\theta_k Y_{s,t}/K_{s,t}$$

$$r_t^{k,m} = q_{m,t}\theta_k Y_{m,t}/K_{m,t}$$

where $q_{s,t}$ is the price of the s good in terms of final goods and similarly with $q_{m,t}$. These prices, in turn, are defined by the marginal product of the m good and the s good in the final goods sector, respectively, so that

$$q_{s,t} = \left(\alpha_s Y_{s,t}^{\xi} + (1-\alpha_s) Y_{m,t}^{\xi}\right)^{1/\xi - 1} \alpha_s Y_{s,t}^{\xi-1}$$

and

$$q_{m,t} = \left(\alpha_s Y_{s,t}^{\xi} + (1-\alpha_s) Y_{m,t}^{\xi}\right)^{1/\xi - 1} (1-\alpha_s) Y_{m,t}^{\xi-1}.$$

Likewise, we have that

$$r_t^{z,s} = q_{s,t}\theta_z Y_{s,t}/Z_{s,t}$$

$$r_t^{z,m} = q_{m,t}\theta_z Y_{m,t}/Z_{m,t}$$

Various no-arbitrage conditions must hold in equilibrium. The marginal product of labor must be the same and equal to the wage rate in all sectors at all times:

$$w_t = q_{s,t}(1-\theta_k-\theta_x) Y_{s,t}/H_{s,t}$$

$$w_t = q_{m,t}(1-\theta_k-\theta_x) Y_{m,t}/H_{m,t}$$

Also, rates of return on physical capital must be equalized across sectors at all times:

$$\widehat{R}_t^k = \widehat{R}_t^{k,s}$$

$$\widehat{R}_t^k = \widehat{R}_t^{k,m}$$

and rates of return on intangible capital must similarly be equal across sectors at all times:

$$\widehat{R}_t^z = \widehat{R}_t^{z,m}$$

$$\widehat{R}_t^z = \widehat{R}_t^{z,s}$$

Finally, using equilibrium conditions and the government budget constraint, the aggregate feasibility constraint for the economy reads:

$$K_{t+1} + Z_{t+1} + A_{t+1} = (1-\delta_k)K_t + (1-\delta_z)Z_t + Y_t + R^a D_t - C_t - G_t \qquad (9)$$

where A_t is the net foreign asset position of the country; it is the aggregate counterpart of a_t in the consumer's budget constraint.

Discussion Three comments are now in order in regard to our model economy. First, as noted above, it is *not* the case that rates of return are necessarily equalized at all times across the three types of assets (physical capital, intangible capital and bonds). The rate of return on foreign bonds is always R^a. The other rates of return are determined by the following equations, which hold for $t = 0, 1, \ldots$:

$$-u_{c,t} + \beta u_{c,t+1} \widehat{R}^k_{t+1} + \varphi \lambda_t = 0,$$

$$-u_{c,t} q_t + \beta u_{c,t+1} = 0,$$

$$-u_{c,t} + \beta u_{c,t+1} R^a + \lambda_t = 0,$$

and

$$-u_{c,t} + \beta u_{c,t+1} \widehat{R}^z_{t+1} = 0,$$

where λ_t is the Lagrange multiplier on the collateral constraint (3).

It follows that

$$\frac{1}{q_t} = R^z_{t+1} \geq \widehat{R}^k_{t+1} \geq R^a$$

for all $t = 0, 1, \ldots$ so that the rate of return on domestic government bonds and intangible capital may exceed the rate of return on physical capital, which may in turn exceed the rate of return on foreign bonds.

Second, in the context of an open economy it is natural to define a notion of Gross National Product (GNP)—Gross Domestic Product plus income from net foreign assets. In terms of our notation, GNP is given by

$$GNP_t := Y_t + (R^a - 1) A_t.$$

We use this notion later on to compare the performance of our small-open economy in light of data.

Finally, we note that the government budget constraints (7) together with (8) imply a standard present-value constraint for the government. Thus, given current and future values of government consumption and transfers, and an initial condition on government debt, not all tax rates can be exogenously specified if the intertemporal budget constraint is to hold. In our subsequent exercises, we impose exogenous values of tax rates on business income, and exogenous ratios of government consumption and transfers to GDP, and set the tax rate on labor income in such a way as to balance the intertemporal budget constraint.

4 Parameter Values and the Quantitative Exercise

Our quantitative experiment has two parts. The first is to establish a benchmark that fits certain salient facts. The second is to explore various hypothetical scenarios with a view to providing a quantitative assessment of the importance of each of the factors that may have contributed to Ireland's rise.

Our overall strategy for establishing a benchmark consists in choosing parameters as well as policy instruments in order to match the evolution of Irish tax and government spending policy as well as GDP, as it evolved year by year. For computational purposes, as far as the benchmark exercise is concerned, we can think of GDP growth in excess of trend as being exogenously given, whereas the path of residual TFP ($\bar{A}_t$) is determined by computing the equilibrium. Similarly, the entire sequence of business tax rates and ratios of government consumption and transfers to output are exogenously given from data, but the labor tax rate is determined so as to balance the intertemporal government budget. Households fully and correctly anticipate all future changes in policy and technology. This overall strategy enables us to establish our benchmark economy, which is designed to fit the facts in certain key dimensions.

In Section 5 below, we go on to provide a quantitative assessment of the significance of each contributing factor (tax reform, government spending reform, residual TFP) by carrying out a set of computational experiments designed to

capture hypothetical scenarios. In each of these hypothetical scenarios, a particular factor is either removed (e.g. there are no changes in business tax rates) or that factor is the *only* thing that changed after 1980.

We now describe our choice of parameter values defining preferences, technology and fiscal policy. We fix initial conditions by computing the steady state of a model economy designed to match observations from 1980 and earlier, and this initial steady state is a necessary input into the computation of a final steady state (designed to match facts about Ireland in 2005) as well as the entire path in between. We examine the robustness of our findings to underlying assumptions later on.

Time Each time period corresponds to one year.

Preferences Since, in a steady state, the subjective discount factor β is equal to the reciprocal of the rate of return of net foreign assets, which in turn equals all other after-tax rates of return, we set it so as to reproduce a rate of return of 4 percent in a steady state; The parameter governing the curvature of the disutility of labor, ε, is set to 0.75. This implies a Frisch elasticity of the same value, which lies on the low side of macroeconomic estimates. The parameter ψ representing the weight on the disutility of labor in the utility function only defines the unit of measurement for labor supply; it has no meaning beyond that, and so its precise value has no relevance for the results we report.

Technology The physical capital share is assumed to be $1/3$, in line with standard assumptions in the macroeconomic literature. The depreciation rate of physical capital is set to in order to match the average tangible investment to output ratio prior to 1980 (1950-1980), which was about 0.183. The resulting depreciation rate is 0.085.

The non-manufacturing share of output, α_s, is set to 0.79 to match the average

manufacturing share during the period 1980-2005 which was about 0.21. Meanwhile, the parameter ξ determining the elasticity of substitution between manufactures and non-manufactures is set to zero to replicate the fact that there is no discernible trend in the manufacturing share during the period.

The intangible capital share (θ_z) is set in order to reproduce the value of an intangible capital to GDP ratio of 1.5 in the final steady state. This corresponds to an intangible capital to GNP ratio of about 1.7, and hence agrees with the analysis in McGrattan and Prescott (2017), who estimate this value for the United States. The resulting value is $\theta_z = 0.197$. We assume that the rate of depreciation of intangible capital is the same as for tangible capital.

Taxes, Government Consumption and Transfers Government purchases G_t and transfer payments $\mathcal{T}_t$ in the initial steady state are such as to match observations in 1980; in subsequent periods, we match the ratios of government consumption and transfers to GDP year by year.[7] Similarly, in the initial steady state, we set the tax rate on corporate income in each sector according to data in 1980; after that, we use the entire sequence of statutory rates from 1980 to 2005. We then select the labor income tax rate in order to balance the government's budget constraint.

When we compute transitions to the new steady state, we take as given the observed path of ratios of government consumption and transfers to GDP, and also the observed time path of business tax rates by sector. We then determine the time-invariant labor income tax rate by imposing the intertemporal government budget constraint.

Collateral Constraint and Initial Net Foreign Assets In the initial steady state, the ratio of GNP to GDP is a bit less than one. Specifically, it equals the observed

[7]Source: Ireland's Central Statistical Office; Historical, National, Income and Expenditure Tables 1970-1995, Table 5.

value in 1980: 0.967.[8] We target this by setting the appropriate value initial net foreign asset position A_0.

The parameter φ determining the fraction of the physical capital stock that can be used as collateral is set so that the model's long-run value matches the GNP/GDP ratio observed in 2005, which was about 0.86.

Summary Given the path for tax rates, government consumption and transfers, and the initial value for net foreign assets, we select the sequence $\bar{A}_t$ in order to reproduce the growth in GDP in Ireland per adult in excess of a 2 percent annual trend. This implies that GDP per adult in Ireland is about 112% higher than it would have been had it grown at 2 percent per annum. It is worth noting that while 2 percent is usually viewed as the balanced-growth rate in developed economies, and thus a measure of the growth at the frontier, it approximates the Ireland experience relative to the United States very well. In 2005, the ratio of Ireland's GDP per adult to that of the United States, was actually 113.8 percent higher than it was in 1980.

A summary of the calibration is shown in Table 1. Our choices determine a value for φ, determining the tightness of the collateral constraint, of about 1.39, which implies than more than the entire tangible capital stock is collateralizable, suggesting that Ireland was quite open to foreign investment. Our choices also determine values for labor tax rates of 0.438 in 1980, and 0.425—only a very small change in twenty five years. The natural interpretation of this small change is that government consumption and transfers as a fraction of output declined over the period 1980-2005, thereby requiring small changes in the labor tax rate in order to balance the government budget constraint.

[8] Source: Ireland's Central Statistics Office.

4.1 Ireland: 1980-2005

In Figure 5 we see the evolution of GDP per adult in Ireland in the period 1980-2005; by construction, the model's implications coincide with the data. In Figure 6, we observe the extent to which we match the entire time path of the GNP/GDP ratio. As can be seen there, the model's implications look like a smoothed version of the data. Thus, our quantitative conclusions are in line with the gradually growing gap between GDP and GNP that we observe in the period. Note here that we force the model to match only the terminal data point of the GNP/GDP ratio.

In Figure 7, we can observe the residual TFP sequence $\{\bar{A}_t\}_{t=0}^{25}$ that is required in order to replicate the observed growth rates (above trend) in GDP per adult. Two properties of this sequence are striking. First, the level of TFP is essentially constant until about 1995. Second, the level of TFP is only 20 percent higher in 2005 than in 1980. The first property is particularly interesting given the dip in GDP per adult in the first 5-6 years, which is connected to a fall in hours. In turn, in the context of our model, this fall in hours is driven by the anticipation effects of future fiscal policy and residual TFP changes. We elaborate on this below and in subsequent sections. The second property is also striking. To put it in perspective, we may ask how much output would go up in the long run as a result of a 20 percent increase in TFP in a standard one-sector growth model without intangible capital and with a capital share of 1/3. The answer, of course, is $1.2^{3/2} \approx 1.31$, implying just a 31 percent increase in GDP. If instead, we use the overall capital share assumed here—about 0.53—the long-run increase in output would be about 47%. Clearly this shows that factors other than TFP were important. We evaluate the quantitative importance of these factors, and their interplay with TFP changes, in subsequent sections.

We note that we do not explicitly target in our parameterization exercise the time path of hours worked per adult. Figure 8 shows where the model implications compare to data, when model and data are normalized to 1 in 1992. The model

replicates qualitatively the initial dip in hours, the subsequent fall and the fact that hours per adult subsequently recover. As the figure shows, the model misses the behavior (level) of hours in the early part of the period. We return to the issue of labor hours, and changes in labor more generally, later in the paper.

5 The Quantitative Importance of Fiscal Policy

We now assess the quantitative importance of the policy-driven forces—changes in taxation and government spending—on the performance of the Irish economy, and how those forces interacted with residual TFP changes. We do this by considering each these forces in isolation, and also by dropping each factor one by one, assuming that it stayed the same from 1980 to 2005. In doing so, we provide our model estimates of the contribution of changes in fiscal policy to the Irish miracle.

5.1 Tax Reform

What is the contribution of the gradual reduction in business taxes to the Irish miracle? We answer this question in two ways, shown in Figure 9 and Figure 10, respectively. Figure 9 shows what, according to our model, would have happened if observed business tax reform were the *only* exogenous change that took place during the relevant period. Meanwhile, Figure 10 shows what would have happened to output if all other exogenous factors had evolved as in the benchmark exercise, but business taxes had stayed at their 1980 levels. Table 2 summarizes the predicted effects of the tax reform in isolation on output, hours worked and the GNP/GDP ratio.

Our findings indicate that tax reform leads, in itself, to large changes on output in the long run; about 26 percent. However, these effects are only about a fifth of the overall changes in output—112 percent. Put differently, despite the amplifying effects of intangible capital in the context of an open economy, the consequences of tax reforms on output are a mere fraction of the observed effects. Hence, any

assertion that the Irish miracle is centered around the reduction in corporate taxes does not hold in the context of our model economy.

As Table 2 shows, the expected changes in taxes lead to a substitution of hours worked over time. Hours fall initially and remain below initial values for a few periods, and then increase gradually to eventually overshoot the initial level. The increase in hours worked in our economy is sharp and amplified by the explicit consideration of the exercise in an open economy. Note that as capital flows into the economy from abroad, GNP grows less over time than GDP. This determines a stronger wealth effect in labor supply—relative to the case of an closed economy—that amplifies the rise in labor supply in the second part of the period.

When interpreting the effects of tax reform, it is important to keep in mind that the Irish reform involved not only a reduction in business taxes, but an equalization of taxes across sectors, thus reducing not only a distortion affecting the overall size of the (tangible and intangible) capital stock, but eliminating an intersectoral distortion as well. To put things further in perspective, it is worth noting that, when tax reform is the only driving force, the labor tax has to rise to balance the intertemporal budget constraint, whereas the labor tax is essentially constant in our benchmark exercise, as Table 1 shows.

If instead we focus on the other driving forces as shown in Figure 10—TFP and public spending—when taxes remain at the levels of 1980, we find a long-run increase in output of about 68 percent. This change is rather substantial and higher than the case of tax reform. Overall, these findings highlight the complementarity between tax reform and the other driving forces in accounting for the output changes in the long run; see below.

5.2 Changes in Public Spending

We now examine the effects of changes in government consumption and transfers in the context of our model economy. It is of course important to note that government spending increased enormously during the period; it would be quite

misleading to speak of any "austerity" in Ireland. Indeed, government consumption increased by about 52 percent above trend or 149 percent overall. Meanwhile, transfer payments as a share of GDP did not change much during the period, briefly increasing in the 1980s but then returning to the original level of about 9 percent; meaning, of course that the ratio of transfer payments to GNP actually *increased* by about a percentage point from 1980 to 2005.

Figure 11 illustrates the implications of the observed reductions in public spending relative to GDP, if these reductions had been the only exogenous change in Ireland during the period. The reduction in government size leads to a reduction in distortionary labor taxes, which in turn determine an increase in labor supply, an corresponding increases in the marginal products of capital and capital inflows. In any case, as the figure shows, the implied changes in output are small (6%), and of second order relative to the overall changes in the period.

What is the overall role of fiscal policy? In Figure 12 and Table 2, we describe the predicted effects associated with tax reform and changes in government spending taken together, assuming that TFP had remained on trend. In this hypothetical case, the overall increase in output is about 36%. This is substantial. Yet, this change amounts to only a third of the actual change in relative output that took place in the period.

5.3 Discussion

What, apart from fiscal policy, accounts for the observed changes in output in the period 1980-2005? Put differently, what was the contribution of changes in TFP on output in this period? Figure 13 shows what, according to our model, would have happened if the increase in TFP were the only exogenous change that took place during the relevant period.

Our findings indicate that changes in TFP in itself are a major factor in accounting for the Irish miracle. Figure 13 shows an effect of about 62 percent in the long run. This represents about 55 percent of the total change in output in the period.

That is, our open-economy predicts an important role for residual changes in TFP, above and beyond the changes in taxation and government spending.

In summary, three points are central from our findings so far. First, our model economy predicts large effects from tax reform, but these effects are of second order in relation to the size of output changes observed in Ireland. This is true despite allowing for international capital movements and the amplifying effects of intangible capital. Second, the inferred changes in residual TFP appear central in accounting for the Irish miracle. Whatever these increases in productivity represent, they are key; without them, the model predicts increases in output that are only about a third of the actual ones.

Finally, the changes in the three driving forces complement or reinforce each other in significant ways. Note that the sum of the independent changes in output ($26 + 62 + 6$ percent) is non-trivially smaller than the overall change in the long run. These changes in isolation account for about 83-84 percent of the total changes in output.

6 Results in Perspective

In this section, we attempt to put our results in perspective. We evaluate the quantitative importance of different features of our environment for our findings. We first assess the importance of considering the Irish miracle in the context of an open economy. Second, we evaluate the role of changes in labor supply, both in terms of changes in hours of work as well as in terms of potential changes in labor quality. Third, we evaluate the importance of intangible capital for our findings. Finally, we provide welfare calculations that shed light on the importance of the Irish miracle and the policy tax changes.

6.1 The Role of Openness

Is it key to study the Irish experience from the standpoint of an open economy? Did openness matter? To answer this question, we examine what would have happened if Ireland had been closed to foreign investment. Specifically, we take the driving forces in our baseline exercise for the period 1980-2005, including the inferred increase in residual TFP, and we compute the corresponding transition path. As seen in Figure 14, the increase in GDP would have been dramatically smaller; only 46 percent by the end of the period or less than *half* of the observed changes (112 percent). If we specifically focus on the role of business tax reform, the consequences are also sharply different from the equivalent exercise in our (open) benchmark. In this case, output (GDP) increases by only about 7.5% from 1980 to 2005.

What accounts for the differences in the behavior of a small open-economy and a closed one? The main reason is due to the delay in growth that a closed economy implies. Foreign investment obviously speeds up the process of convergence to a new balanced growth path, resulting in a growing gap between GDP and GNP. Given more time, our model implies that GDP would eventually settle down at about 82 percent above trend in a new steady state. Thus, our model—disciplined to account for the GDP/GNP gap—predicts a substantial role from openness in accelerating convergence to a new balanced-growth path.

The remaining gap (from 82 to 112 percent) is accounted for by the much larger implied rise in labor supply that takes place in an open economy and its implications. The benchmark exercise leads to a substantial increase in hours worked by 2005—18.9 percent—whereas the hours increase is only 4.8 percent in the closed-economy case when all driving forces are in place. For the case of business tax reform only in the context of a closed economy, hours worked *decline* by about 3.3% by the year 2005. The reason for this difference between closed and open economies is that the growing gap between GDP and GNP in an open economy implies that domestic wealth increases less than wage rates. Thus, even under

preferences consistent with a balanced growth path, income and substitution effects induced by all driving forces do not necessarily cancel out. It follows that, other things being equal, the predicted changes in labor supply are larger in our baseline exercise than in the context of a closed economy.

From these findings, we conclude that considering the Irish miracle in the context of an open economy is key. Much larger changes in residual TFP would have been needed in order to generate the increase in large observed increases in output in a traditional, closed-economy setup. Similarly, changes in business taxes would have led to non-trivially smaller effects in a closed economy scenario.

6.2 The Role of Labor Supply

What is the quantitative importance of changes in hours of work, and labor supply more broadly, for our analysis and conclusions? We answer this question in two ways. We first evaluate the transitional dynamics that ensues when the labor supply elasticity is lower than in the benchmark case. Second, we evaluate the potential importance of changes in labor efficiency units as a driving force for the Irish miracle.

Lower Labor Supply Elasticity Recall that in our open-economy model, the driving forces we entertain lead to substantial changes in labor supply in the period 1980-2005. Those changes have direct effects on output, as well as indirect effects via increases in in the domestic marginal products of capital that result in further capital accumulation and inflows. If labor supply reacts less to changes in the driving factors that we consider, these indirect effects are naturally absent. We now examine the role of labor supply changes by considering a case in which cases the labor supply elasticity is much lower than macroeconomic estimates: ($\epsilon = 0.25$). For this case, we recalibrate the model following the procedure outlined in Section 1.

Repeating our baseline experiment under a lower labor supply elasticity, the re-

quired increase in residual TFP in the 1980-2005 period is larger than in the benchmark case—25.3 versus 20.0 percent. For the special case of tax reform only, our results indicate that the endogeneity of labor supply is not of first-order importance for our findings on output. We find that the predicted effects on output decline as the elasticity is reduced, but not by much. The increase in output by 2005 is 26.1 percent in our benchmark case, while the increase is 23.5 percent under the low elasticity value ($\epsilon = 0.25$). If we assign hours worked *exogenously* according to the patterns observed in data, i.e. hours are no longer a choice, the predicted increase in output is 23.3 percent.

We conclude from these findings that the endogeneity of work hours has non-trivial implications for the interpretation of the driving forces of the Irish miracle. This follows as the required increase in residual TFP to match the observed output increase is non-trivially bigger under a low labor supply elasticity. However, a labor supply elasticity on the low side of empirical estimates does not appear central for the predicted effects of business tax reform.

Changes in Labor Quality As we noted in Section 2, the educational attainment of the labor force went up in the period 1980-2005. We now evaluate the potential importance of these changes alongside the baseline driving forces in this period.

As we noted earlier, Ireland average years of schooling went from around 9.9 in 1980 to about 11.9 years in 2005.[9] Using this data, we construct an index of labor quality using years of schooling and Mincerian returns. We assume that as in Hall and Jones (1999), Caselli (2005) and others, individual efficiency units are given by $\exp[\Psi(s)]$, where Ψ is a function of years of schooling (s) and is determined by rates of return that vary with average years of schooling, as in Psacharopoulos (2004). Specifically, we set $\Psi(s) = 0.134s$ for $s \in [0, 4]$,

$$\Psi(s) = 0.134 \times 4 + 0.101(s - 4)$$

[9] According to Barro and Lee (2010), years of education were 9.9 in 1980, 10.6 in 1985, 11.1 in 1990, 11.5 in 1995, 11.7 in 2000 and 11.9 in 2005.

for $s \in (4, 8]$, and

$$\Psi(s) = 0.134 \times 4 + 0.101 \times 4 + 0.068 \times (s - 8)$$

for $s > 8$. We linearly interpolate between years of data to construct yearly indices. Overall, these calculations imply that the quality of the Irish labor force increased by about 14 percent in the period 1980-2005.

We now repeat our baseline experiment but with accompanying changes in labor quality. We find that the required changes in residual TFP from 1980 to 2005 are lower than in the original baseline experiments—about 14 percent versus 20 percent. In this case, it is worth noticing the significant complementarity between changes in labor quality and other driving forces, particularly tax reform. We note that if we repeat the experiment of a tax reform in isolation, but with the underlying changes in labor quality in the background, the effects are non-trivially larger than before. In the baseline experiment, tax reform alone leads to changes in output of about 26 percent by 2005. With concomitant (but exogenous) changes in labor quality, the business tax reform implies much larger changes in output, of about 37-38 percent by 2005.

Overall, it is worth noting these findings are arguably an upper bound for the potential effects driven by changes in labor quality. Neighboring countries in Europe in a similar environment, experienced much *larger* changes in an equivalent notion of labor quality and no corresponding output miracle. In France, labor quality went up by 40.6 percent. In Spain, the changes were even larger; 55.6 percent. From this perspective, one conclusion is that the potential effects of changes in labor quality in the Irish miracle were moderate. Nonetheless, given the complementarity of labor and capital in production and the amplifying effects in an open economy, the predicted effects from changes in business taxation are substantially larger when labor quality varies.

6.3 The Importance of Intangible Capital

So far we have conducted our analysis assuming that the share of intangible capital services in production is non-trivial, leading in turn to an overall share of movable and reproducible factors of about 53%. Our benchmark large share of capital, tangible and intangible, effectively biases our results in favor of large predicted effects of changes in business taxation, and reduces the importance of residual changes in TFP to account for the observed changes in output. We note, as others do, that it is not easy to pindown the importance of intangibles in production. Hence, understanding the quantitative implications of an alternative parameterization provides an important perspective on our findings.

In this section, we simply ask: what if the intangible share in output is (much) lower than what we assumed in our benchmark case? We assume exogenously that the share of intangibles about half of the benchmark value, $\theta_z = 0.10$ (instead of $\theta_z = 0.197$), and calibrate the rest of parameter values following the procedure described in section 4.

We find that under $\theta_z = 0.10$, the required increase in residual TFP is 29.6% from 1980 to 2005, instead of 20% as in the benchmark case. The effects of changes in business taxes on output when all other forces are shut down is of about 18% for the period, instead of 26% in the benchmark case.

Interestingly, repeating the exercises in section 6.1, we find that the effects on output from 1980 to 2005 of all driving forces if the economy is closed to capital movements is larger than in the benchmark case; about 55% vs 46% in the benchmark case. What accounts for this result? First, the residual increase in TFP is larger under $\theta_z = 0.10$. Moreover, as it is well known, the share of reproducible factors is a key determinant of the speed of convergence to steady states. In a closed economy, all the same, output naturally responds faster to exogenous changes when such share is small under $\theta_z = 0.10$ than under the benchmark case.

Two conclusions emerge from these exercises. First, the share of intangibles in

production is important for the quantitative interpretation of the driving forces that account for the changes in output. Not surprisingly, tax reform becomes quantitatively even less important when the share of intangible capital is reduced by about half of its benchmark value. Second, if intangibles are less important in production, then openness to capital movements becomes quantitatively less important in understanding the Irish miracle.

6.4 Welfare Effects

What are the welfare effects of the Irish miracle from the perspective of our model? Answering this question provides further perspective on the quantitative role of the driving forces that we consider, as well as on the features of our environment.

Our notion of welfare changes is standard: we compute the consumption compensation that equates the discounted utility between the transition path to the new steady state—driven by tax reform, TFP changes and government spending—and the status quo in 1980. We present results in Table 3. Not surprisingly, we find a rather substantial increase in the welfare of the representative household in our baseline experiment (column 1). We find that when all driving forces are operational, the Irish miracle in our model leads to a gain equivalent to a permanent 41.1 percent increase in consumption, starting in 1980. Despite its unusual size, it is worth noting that the required increase in consumption is much smaller than the reported increase in GDP by 2005 (112 percent). This should not be surprising given the forces at work in our dynamic, open-economy model.

Does openness matter for the welfare gains? The second column in Table 3 answers this question in the affirmative. There we report the welfare effects resulting from the same driving forces as in the benchmark case but when the economy is closed to capital inflows from abroad. We find that, in this case, the welfare gains are non-trivially reduced by closing the economy. The table shows that gains in this case are 34.1 percent—about 83 percent of the gains in the bench-

mark case. Thus openness clearly matters for welfare gains, even if changes in the environment (e.g. tax reform) happen, from the point of view of 1980, quite far into the future.

Tax Reform How large are the welfare gains attributable to the gradual reduction of business taxes? To answer this question, we undertake a set of experiments specifically designed to quantify the gains associated with such tax changes. We compute the transitional dynamics driven by the changes in taxes assuming that government consumption and transfers are fixed at their initial levels, meaning that they are not proportional to output, as they were in our other exercises. Of course, we require that the tax changes are consistent with the intertemporal budget constraint as we explained previously.

Our findings are in Table 3 for three different cases: the case of benchmark parameter values, the case of a low labor supply elasticity ($\epsilon = 0.25$) and the case of a low value of the intangible capital share ($\theta_z = 0.10$). Table 3 indicates that the resulting welfare gains are sizeable, and amount to about 4.8 percent in our benchmark case. The associated welfare gains are similar in magnitude in the case of low labor supply elasticity (4.0%). Table 3 shows that the gains are not surprisingly lower under a low value of the intangible share (2.6%).

Three things are worth noting about these results. First, the welfare gains are in all cases large by the standards of applied general-equilibrium analysis. Secondly, uncertainty about the underlying labor supply elasticities is not a central concern in an assessment of the welfare gains associated of an episode of gradual reduction of taxes as experienced in Ireland. Our results show that welfare gains do not differ significantly when we sharply reduce the labor supply elasticity. Finally, these findings show that uncertainty about the share of intangibles in production matters significantly for the size of welfare gains in our context. Welfare gains under a low intangible share are about 45% lower relative to the benchmark case.

Overall, these findings indicate that while tax reform is not a first-order driving

force in accounting for Irish output miracle, its implied welfare effects are clearly significant.

7 Concluding Remarks

We have evaluated the economic miracle of Ireland in the period 1980-2005, and the role of fiscal policy in this phenomenal performance. We have conducted our analysis in the context of an open-economy growth model with endogenous labor labor supply with an expanded notion of capital (tangible and intangible), and in which flows of capital from abroad occur but are limited by a collateral constraint. Our findings indicate that the reductions in business taxes in Ireland played a significant, yet secondary role in accounting for the Irish miracle. The same conclusion holds if all changes in fiscal policy are considered. We also find that evaluating the changes experienced in Ireland in the context of an open economy is crucial: we find that the same driving forces that we identified—fiscal policy and residual changes in TFP—would, in a closed economy, have led to a change in output less than half of the change that actually occurred.

We conclude the paper with two comments. The first one pertains to the behavior of labor supply in the period of analysis. Our framework generates the qualitative u-shaped patterns of hours worked per adult, but misses the behavior of this variable in quantitative terms. This holds under the benchmark value of the labor supply elasticity, as well as under a value on the (very) low side of empirical estimates. On this point, we note that large structural changes in the Irish economy played a role. As we noted in Section 2, there was a gradual reduction of hours worked per worker in Ireland over the 1980-2005 period which was accompanied by increases in the employment rate in the latter years of the sample. Notably, this increase in employment rates took place strongly for a key group, namely married women, mirroring a trend in several other countries. Since changes in labor supply can arguably be key in understanding changes in output per capita, future work should investigate miracle episodes like Ireland's in the context of deeper

models of labor supply that consider both the intensive and the extensive margin in the context of multi-member households.[10]

The second point concerns our finding that changes in aggregate TFP are the primary drivers of output changes in the Irish miracle. This holds even when our model includes intangible capital whose presence tends to amplify the effects of fiscal policy, especially in an open-economy context. Future work should shed light on the deeper reasons for these changes in TFP. One interpretation of these TFP changes is related to the forces associated with multinational production emphasized by McGrattan and Prescott (2009). From this perspective, changes in openness to multinational firms would act as changes in TFP. Likewise, changes in the skills of the Irish workforce could be part of these residual changes in TFP. However, such a line of argument needs to allow for the fact that, as we argued in section 6, that similar and stronger changes occurred in neighboring countries in Europe also open to foreign investment. Meanwhile, we conjecture that changes in labor market regulation and labor practices in Ireland may have had substantial effects that were amplified in an open economy context. We leave these and other potential reasons that could rationalize the inferred changes in TFP for future work.

[10] See Cubas (2016) for a recent analysis of the interplay between changes in female labor supply and development in Latin American countries.

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Table 1: Parameter Values

Parameter	Description	Value
β	Discount Factor $(1/R^a)$	0.961
θ_k	Share of Physical Capital	1/3
θ_z	Share of Intangible Capital	0.198
δ_k	Tangible Depreciation Rate	0.085
δ_z	Intangible Depreciation Rate	0.085
ε	Frisch Elasticity	0.75
α_s	Non-manufacturing Share	0.79
$1/(1-\xi)$	Substitution Elasticity Manufacturing vs Non-manufacturing	1.0
φ	Collateral Constraint	1.390
$\tau^{k,m}_{1980} = \tau^{z,m}_{1980}$	Manufacturing Tax Rate	0.10
$\tau^{k,s}_{1980} = \tau^{z,s}_{1980}$	Non-Manufacturing Tax Rate	0.50
$\tau^{k,m}_{2005} = \tau^{z,m}_{2005}$	Manufacturing Tax Rate	0.125
$\tau^{k,s}_{1980} = \tau^{z,s}_{2005}$	Non-Manufacturing Tax Rate	0.125
τ_{1980}	Labor Tax Rate in 1980	0.438
τ_{2005}	Labor Tax Rate in 2005	0.425

Note: This table summarizes the parameter values used in the analysis. See section 1 in the text for details.

Table 2: Implications of hypothetical scenarios

	1980	1985	1990	1995	2000	2005
Tax reform only						
GDP	1.00	0.88	0.97	1.00	1.13	1.26
Hours	1.00	0.88	0.92	0.93	0.98	1.03
GNP/GDP	0.97	0.98	0.95	0.94	0.92	0.91
Fiscal policy reform only						
GDP	1.00	0.95	1.05	1.08	1.22	1.36
Hours	1.00	0.95	0.99	1.01	1.06	1.11
GNP/GDP	0.97	0.96	0.93	0.91	0.89	0.88
TFP changes only						
GDP	1.00	0.92	1.03	1.15	1.44	1.62
Hours	1.00	0.90	0.94	0.99	1.08	1.11
GNP/GDP	0.97	0.95	0.92	0.89	0.88	0.88
Data						
GDP	1.00	0.91	1.12	1.29	1.73	2.12
Hours	1.00	0.88	0.92	0.89	0.99	1.00
GNP/GDP	0.97	0.90	0.89	0.89	0.85	0.85

Note: This table shows the behavior of GDP, hours worked and the GNP/GDP ratio over time in different cases. The first panel shows the case of a business tax reform in isolation. The second panel shows the case of only fiscal policy changes—tax reform and changes in government expenditure. The third panel shows the case of changes in residual TFP only. For comparison purposes, the last panel presents the corresponding values from data.

Table 3: Welfare gains (%)

Baseline Experiment	Baseline Experiment (Closed)	Tax Reform Only	Tax Reform Only ($\epsilon = 0.25$)	Tax Reform Only ($\theta_z = 0.1$)
41.1	34.1	4.8	4.0	2.6

Note: This table presents the welfare effects (consumption compensation) associated to selected cases. The first case corresponds to the baseline experiment with all driving forces at play. The second case corresponds to the same driving forces in the context of an open economy. The last three cases correspond to the welfare effects of tax reform. under benchmark parameter values. The first case of tax reform corresponds to benchmark parameter values. The last two are for a lower value of the labor supply elasticity ($\epsilon = 0.25$) and for a lower value of the intangible share ($\theta_z = 0.1$). See text for details.

Figure 1. Ireland's GDP per adult and Business Tax Rates.

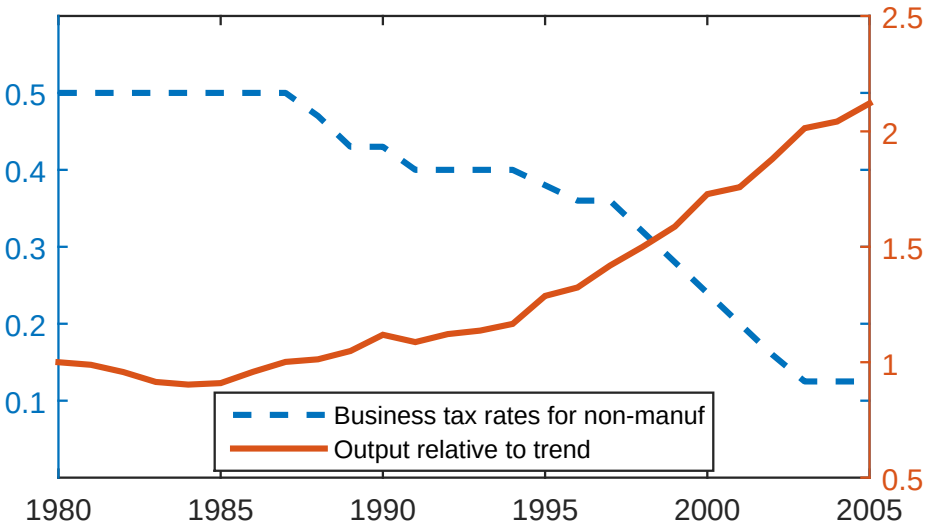

Figure 2. Ireland's GDP per adult relative to the United States.

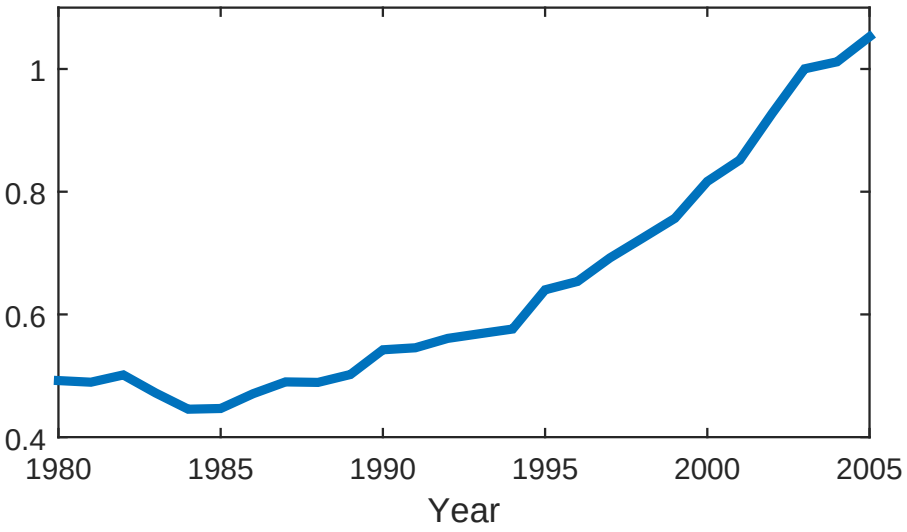

Figure 3. Ireland's ratio of GNP to GDP.

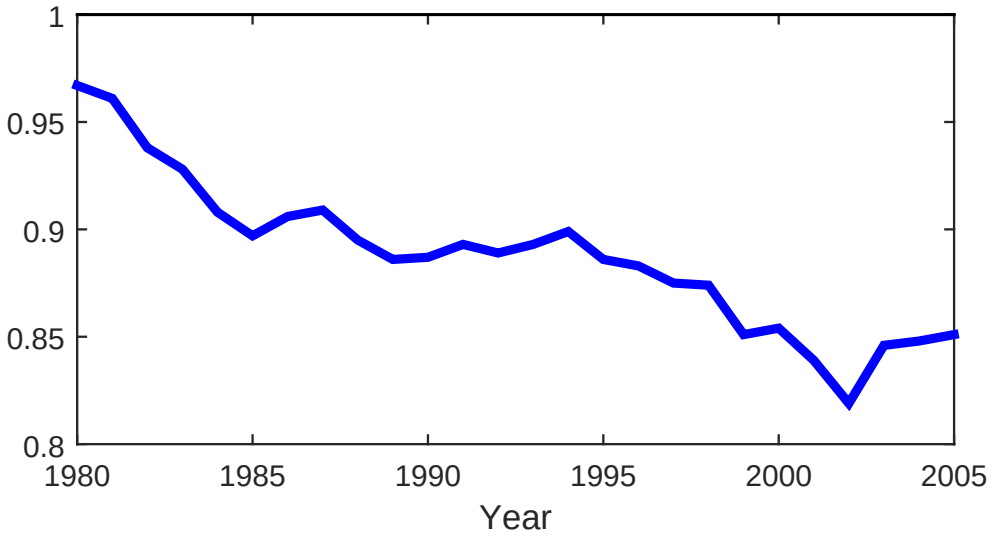

Figure 4. Statutory business tax rates: Ireland, U.S. and the OECD.

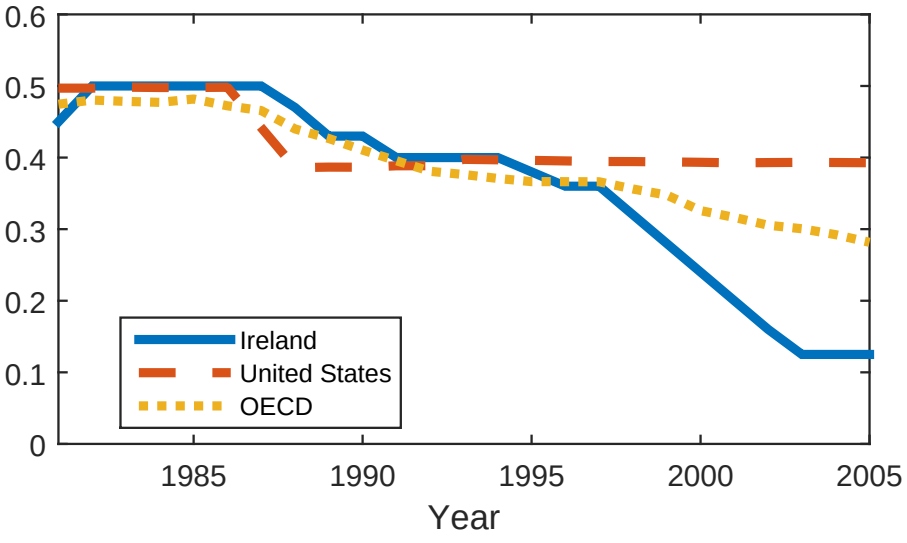

Figure 5. Output: model vs data

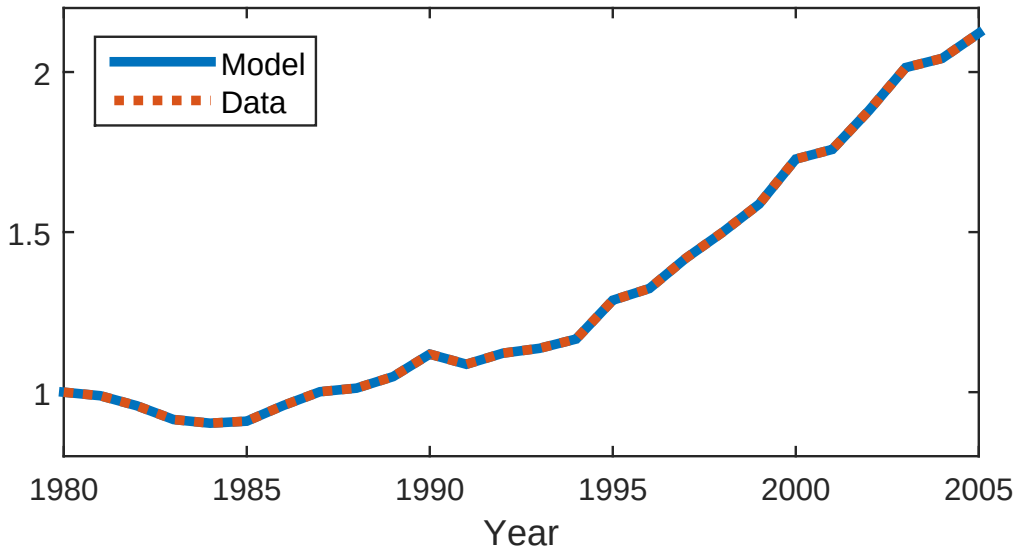

Figure 6. GNP/GDP ratio: model vs data

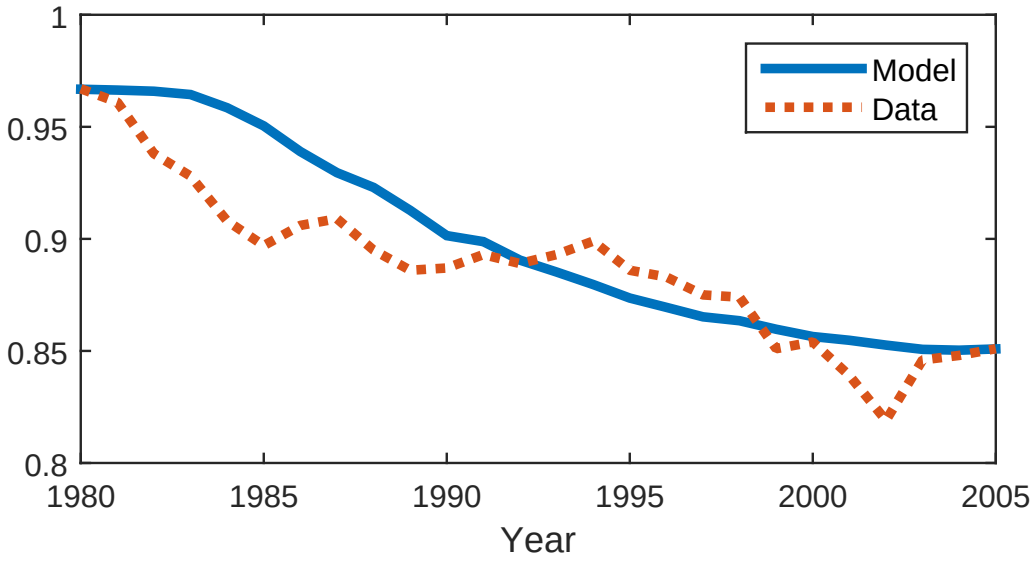

Figure 7. Inferred TFP values

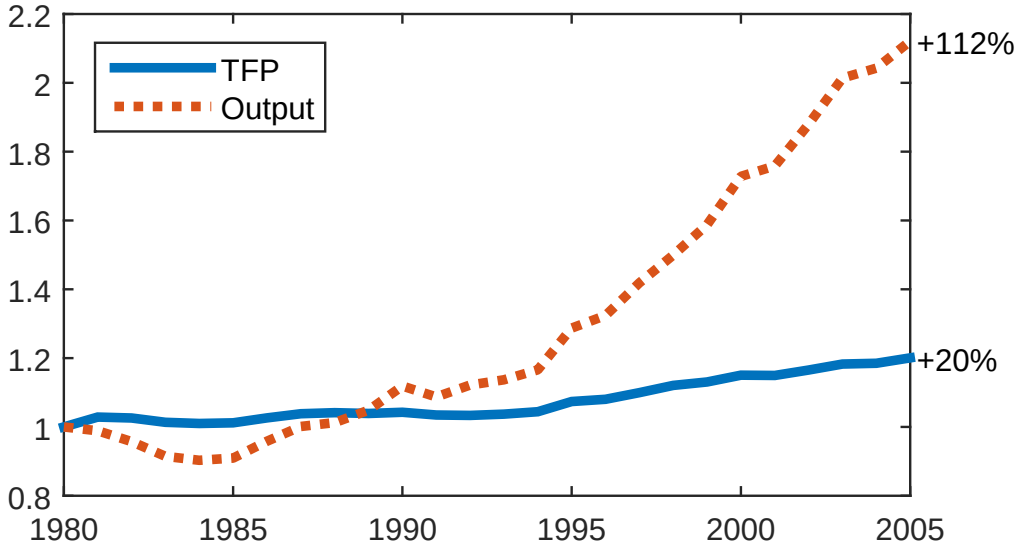

Figure 8. Hours worked per adult: model vs data (1992=1)

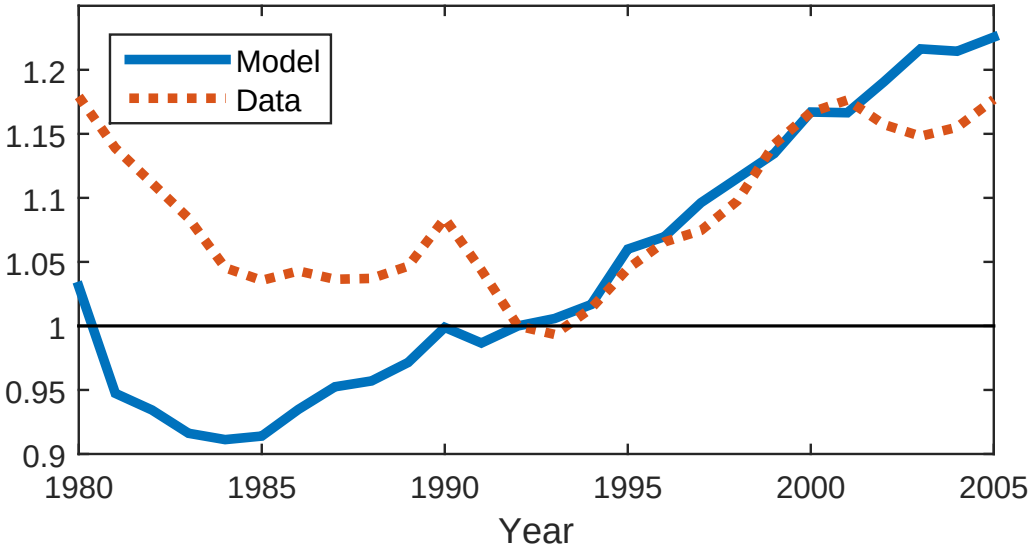

Figure 9. Output per adult: tax reform only

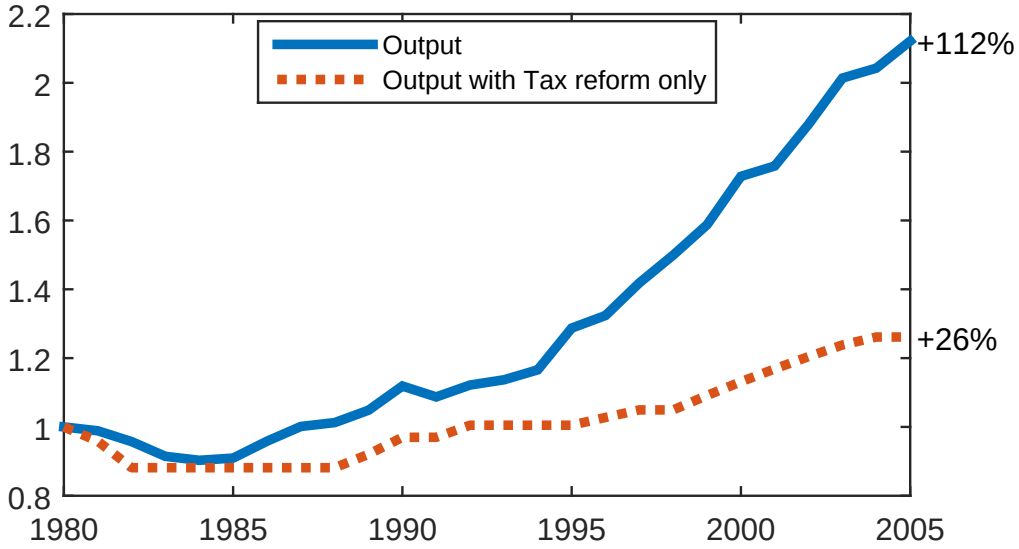

Figure 10. Output per adult: no tax reform

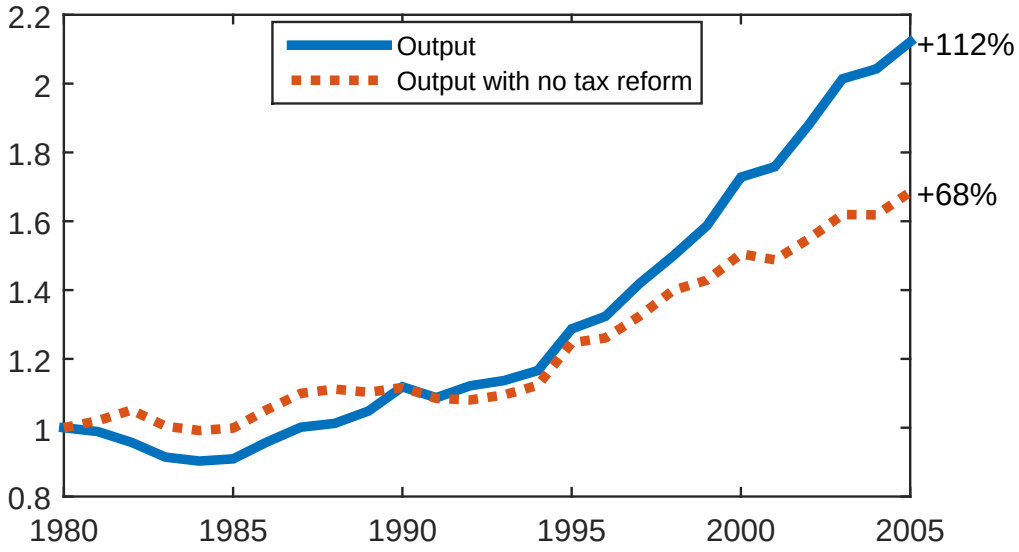

Figure 11. Output per adult: Government spending changes only

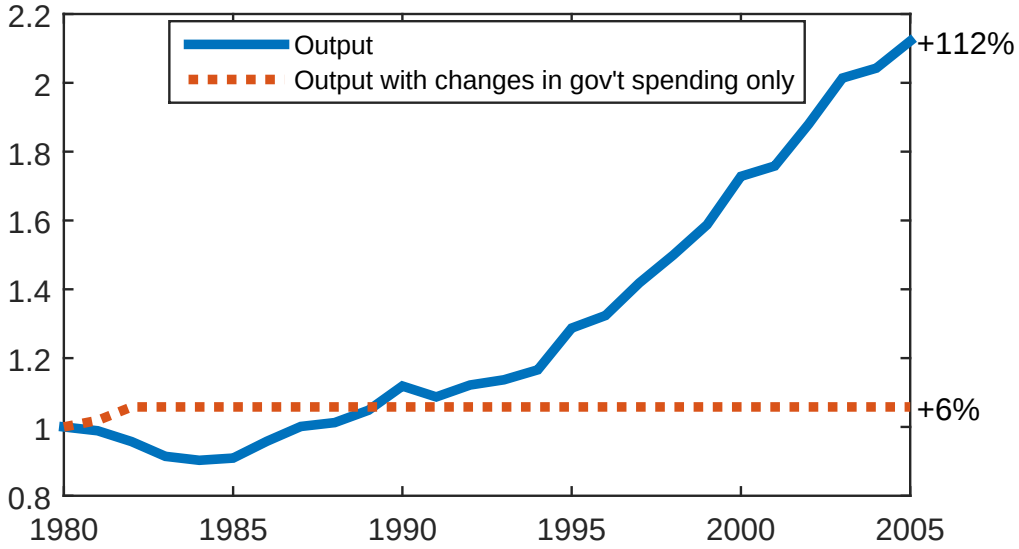

Figure 12. Output per adult: Fiscal policy changes only

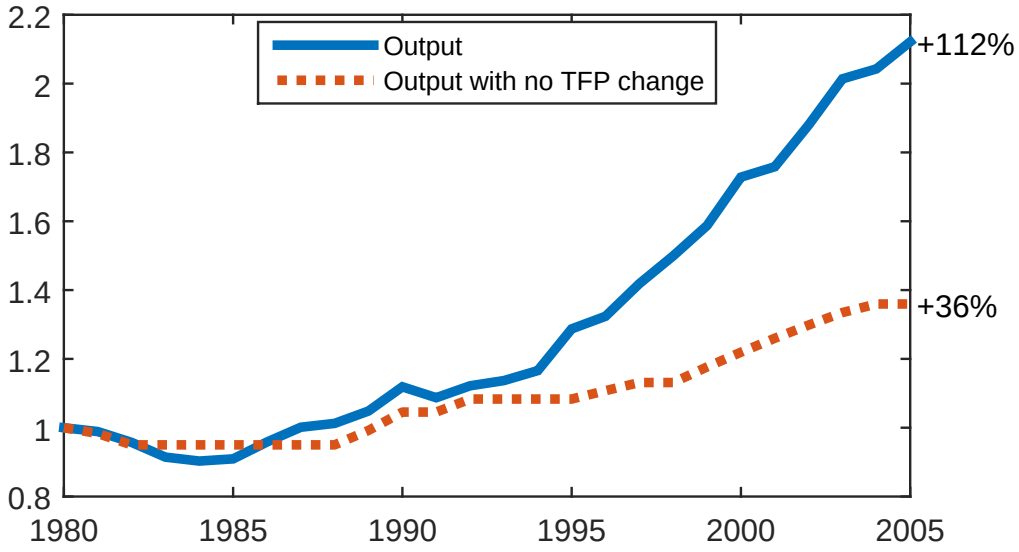

Figure 13. Output per adult: TFP changes only

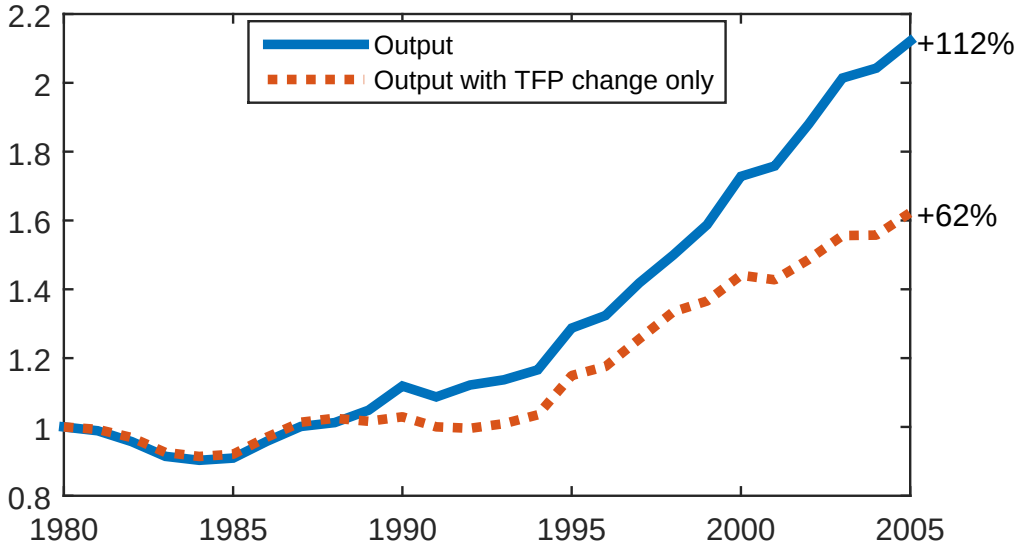

Figure 14. Output per adult: closed vs open economy