THE IMPACT OF R&D, HUMAN CAPITAL AND INNOVATION ON GROWTH: A COMPARATIVE STUDY OF THE PERIPHERAL ECONOMIES OF THE EU THROUGHOUT THE CRISIS

Abstract

Three decades ago, Ireland, Spain, Portugal and Greece were tired, lagging economies, suffering from double-digit unemployment and stagnating incomes. Today, Ireland is one of the fastest growing economies in Europe, with a roaring technology industry, highly-skilled human capital and productivity levels among the highest in Europe. At the same time, the Spanish, Greek and Portuguese economies try to grow in different scenarios in the aftermath of the 2008 crisis at a much lower rate of growth. In this study we present a continuous-time disequilibrium model to explain economic growth in this set of countries and we compare the different experiences and policies implemented by these four governments throughout the last decades. We conclude that policies aimed to foster innovation through R&D, to improve human capital and to attract Foreign Direct Investment, and thus technology, are much more sustainable and effective in creating long-run growth than those policies that neglect these kind of economic policies.

Key words: Peripheral economies, economic growth, Human Capital, Foreign Direct Investment, Research and Development, innovation.

INTRODUCTION

The financial and economic crisis that has hit the world and Europe since Autumn 2008 has had its most severe impact on a few European countries, countries that are often referred to as ‘peripheral’ from the standpoint of the geography of Europe or the EU: Greece, Ireland, Spain and Portugal. Maybe it was their location on the margins of Europe that played a part in their lagging economies compared to their EU partners in the 1970s and 1980s as they all joined the EU (1973 for Ireland, 1981 for Greece, 1986 for Spain and Portugal). And maybe that explained to a certain extent the ‘fast-track’ paths to economic growth that some of them went for then, with the support of European funding for infrastructural upgrades in particular. By 2010, sovereign debt crises—most pronounced in Greece—had spread throughout the periphery, and by 2011 the EU and the IMF had bailed out Greece, Ireland, and Portugal. By 2014, periphery countries, with the exception of Greece and Cyprus, had completed their bailout programs. In December 2013, Ireland was the first country to exit its program. Spain followed in January 2014, and Portugal too exited in May 2014. Growth in the periphery resumed: Ireland is set to be the fastest growing eurozone economy in 2015, having expanded 5 percent in 2014. Portugal is expected to expand 1.5 percent in 2015, and Spain's economy has been growing at a low rate since 2013.

Education, R&D, technology and growth: the special Irish case

According to recent data from the European Commission (2014) most of the European periphery, and especially Greece, Portugal, and Spain, remain at the rear of overall R&D investment. The percentage of GDP devoted to R&D activities in these countries for 2008 and 2013, respectively was: 0.78% and 0.76% in Greece; 1.44% and 1.35% in Portugal; 1.31% and 1.24% in Spain and 1.40% and 1.57% in Ireland, in comparison to a EU average of 1.77% and 1.92%. It declined in all these cases with the exception of Ireland, where amid the deep recession, governments managed to raise the percentage devoted to R&D. Countries in the European periphery, with the Irish exception, are thus trying to close the technology gap, but the gap remains significant. A more detailed analysis shows that it is fundamentally the public sector which has been undertaking the main R&D investments in peripheral countries. In the Irish economy there has been a mixture of private and public spending that has reduced the technological gap.

The Republic of Ireland has been considered as the leader economy in Europe in the last part of the twentieth century. The second half of that century, the Irish economy went through a diversity of sweet and sour situations: the fifties and sixties contributed to the expansion of Ireland, as it happened with the rest of most important economies; the early seventies, conditioned by the Oil Crisis, took down the standards of living of the Republic gained at the precedent decade; after a short period of recovering, Ireland had to face again the ghost of emigration of young-skilled population to other countries in the mid-eighties as it had happened in previous decades in the mentioned Century; after this loss of economic speed coming from the sixties, the Island started to receive financial funds from the European Union as a country that did not represent the 90% of total European GDP. After these decades, in the nineties, Ireland suffered a suitable called "economic miracle" and was launched to the highest rates of growth in the world as it would have never dreamt. Due to that cocktail of economic factors, Ireland is known as "Celtic Tiger", as it has been compared to the economic model of the NICs in the southeast part of Asia. As countries develop economically, and move beyond a narrow cost-based growth model, productivity gains through innovation and research acquire an added importance. For most of the 1990's, the Irish economy was expanding at three times the EU average, a pattern of growth. Even, Ireland got around the crisis in those years growing while the rest of developed countries suffered a sharp fallen in the growth of GDP. There is broad agreement that the key factors that fostered the takeoff of Irish economy in the last decade are emphasis on education and technological innovation. Education and Training is a vital component of Ireland's knowledge-based economy, and it has been a priority investment under the National Development Plan. The Irish education system has long been recognised as one of the most successful in the world in meeting the needs of business. It has played a major part in the impressive growth of the Irish economy over the last decades. Its highly skilled graduates have been a key attraction for inward investors. The quality of skills and learning, raising public awareness and acceptance of the importance of the sciences. Increasing participation at third level and beyond in science, technology and engineering disciplines. Investing in Research & Development capabilities both in universities and in industry. Substantial inward investment inflows; inward investment (FDI) has been critically important to Ireland's economic development, providing tens of thousands of jobs, dissemination technological know-how and expertise within the wider economy, linking up with indigenous industry, boosting productivity, and underpinning export growth

At this point several questions can be asked. Does the increase in investment in R&D pay off in terms of innovation and economic growth? Does private, public, and higher education R&D investment yield different results in the innovation process? How much do they differ in fostering innovation? Does the rate of innovation play a role in fostering economic growth across different peripheral economies of the EU? Do the economies implementing these technology-oriented policies grow at a higher rate than the rest of economies? The aim of this work is to explain the above mentioned phenomenal economic growth by measuring the impact of those main variables and to answer these questions. The paper is organized as follows. In section 1 we present the theoretical framework used to construct the model. In section 2 the different equations of the model are given. Section 3 presents econometric results and section 4 concludes.

1. THEORETICAL FRAMEWORK

Research and Development, technology and economic growth

It is widely accepted that technology and technological advances are a key component of innovation and economic growth. Grossman and Helpman (1994), for instance, observe that technology has been “the real force behind perpetually rising standards of living”. Traditionally, investment in R&D has been regarded as one of the key strategies to secure technological potential and therefore, innovation and economic growth (Trajtenberg, 1990). R&D investment increases the possibility of achieving a higher standard of technology in firms and regions, which would allow them to introduce new and superior products and/or processes, resulting in higher levels of income and growth. Equally, Romer (1990) and Lichtenberg (1992) have shown the relationship between investment in technology and R&D expenditure and increases in productivity and growth. Some scholars (Scherer, 1982) have highlighted the existence of increasing returns to investment on R&D activities. These increasing returns arise thanks to the positive economies of scale and scope derived from further concentration of these activities. In this sense, Dosi (1988) argued that “returns on investment in R&D tend to be positively associated to the volume of investment and benefit from strong cumulative effects”. It is this idea of ‘cumulative effects’, maximising the positive externalities related to the agglomeration of R&D activities that Audretsch and Feldman (1996) considered in their work, reaching the conclusion that “accumulation of R&D activities would lead to the maximisation of knowledge spillovers and to higher growth”. Other authors such as Smulders and Van de Klundert (1995) or Verspagen (1997) have also emphasised the idea of the existence of a virtuous circle triggered by the accumulation of positive externalities, leading to higher growth.Therefore, the relationship between these variables (from R&D investment to technological potential and from here to innovation and growth) seems to show the path policy makers should follow in order to secure economic growth in any given region.

Demand-side oriented growth models

One of the main aims of growth theory has been to explain why growth rates differ across countries over time. The pioneering studies trying to answer this question were based on a neoclassical framework and, as a result, concluded that most growth differences could be explained by the diversity of growth rates of the inputs that made up the production function. In recent years, a new approach, the so-called endogenous growth theory, has stressed the role played by the production function. Thus, endogenous growth theorists argue that not only does growth vary across countries because of their *dynamic* resource endowment, it also varies to an important extent according to the *form* of the production function. Both approaches, however, are supply-side-oriented and give no role to demand. When a country has factors to be employed and a production function, it is assumed that it will grow and no attention needs to be paid to where the goods produced are consumed. Nevertheless, this is only true under unrealistic assumption that there is only one sector in the economy; in an economy with more than one sector and different degrees of return to scale, demand plays a crucial role in growth since it affects the endogenous process. Thus, in order to explain why growth varies across countries and over time, it is necessary to pay attention not only to the discrepancies in the growth of inputs and to the shape of the production function but also to the form of the demand function.

This being true for a closed economy, it also holds for an open economy. In order to grow, a country that trades with the rest of the world not only needs inputs. It also needs to be able to sell the new goods produced. Because of the structure of consumption, a country cannot consume every new good produced and it needs to exchange some of them for other goods that better fir domestic demand patterns. Since in a pure neoclassical framework every country can sell the goods produced at the international price, this fact does not add anything new to the standard one-sector theory. But if price elasticity is not infinite, the country must reduce either the selling price –thus worsening the terms of trade- or potential output.

Traditionally, the demand-side-oriented approach to growth based on Harrod´s study argues that prices do not play an important role and that the adjustment process is carried out mainly through changes in output. Thus, a country´s capacity to grow could be constrained by balance of payments. More specifically, Thirlwall (1979) assumes that the long-run rate of growth can be proxied by the ratio of export and import income elasticities multiplied by the foreign growth rate. In this article we maintain that the assumption defended by Thirlwall (1979, 1997, 2001, 2003) that prices do not matter in determining the equilibrium income is neither necessary nor sufficient to affirm that growth is constrained by balance of payments.

Harrod´s multiplier and Thirlwall´s law

The first important contribution to a balance-of-payments-constrained growth theory was the model developed by Harrod (1933), who thought that exports played the role of the independent variable which governed output and employment. As said before, a later version of Harrod´s model was developed by Thirlwall (1979). According to this model, the trade balance is supossed to be in equilibrium in the long run so,

$$XP = MP^{*} \qquad (1)$$

where denotes export volume, import volume, the domestic price level, and the foreign price level, both expressed in a common currency. In addition, trade functions are defined as

$$X = A\left(\frac{P}{P^{*}}\right)^{\gamma} Y^{*\varepsilon} \qquad (2)$$

$$M = B\left(\frac{P^{*}}{P}\right)^{\eta} Y^{\pi}$$

where and are constants, and stand for world and domestic income, respectively, and are price elascities of imports and exports, respectively, and are import and export income elasticities, respectively. Taking logs and time derivatives, we can get the dynamic version of equations 2,

$$\dot{x} = \gamma\left(\dot{p} - \dot{p}^{*}\right) + \varepsilon\left(\dot{y}^{*}\right) \qquad (3)$$

$$\dot{m} = \eta\left(\dot{p}^{*} - \dot{p}\right) + \pi\left(\dot{y}\right)$$

Plugging equation (3) into the dynamic version of equation (1), we obtain the rate of growth of income consistent with trade balance equilibrium:

$$\dot{y} = \frac{(1+\gamma+\eta)(\dot{p}-\dot{p}^*)+\varepsilon(\dot{y}^*)}{\pi} \qquad (4)$$

In Thirlwall´s model, relative prices do not play any role for two reasons that are, to some extent, mutually incompatible. The first refers to the stability of relative prices in the long run so that PPP theory holds. The second suggests that price elasticities are very small, so the term $(1+\gamma-\eta)(\dot{p}-\dot{p}^*)$ is close to 0. Hence, according to Thirlwall, equation (4) may be written as:

$$\dot{y} = \frac{\varepsilon\dot{y}^*}{\pi} \qquad (5)$$

an expression that is known in the literature as Thirlwall´s Law. The meaning of this equation is that, in the long run, growth depends only on external income growth multiplied by the ratio of income export and import elasticities.

Some limits on Thirlwall´s approach

Although Thirlwall´s model has been generally supported by empirical research, in our opinion it suffers from both theoretical and empirical shortcomings that may make its conclusions less tenable (Alonso y Garcimartín, 1998, 1998-99).

Three types of shortcomings are worth noting here: (a) Trade functions may not be properly defined for countries that experience significant changes in the structure of their output; (b) the empirical methodology used to test Thirlwall´s Law shows some econometric shortcomings –the variables are commonly measured by growth rates instead of levels; income is assumed to be either an exogenous variable in the import function or an endogenous one in the equilibrium growth equation; the estimate of equation (5) includes a nondeterministic variable; and (c) the null impact of relative prices on growth is not necessary to justify the balance-of-payments-constrained growth developed in this study tries to avoid these shortcomings. Yet, generally speaking, the empirical work supports Thirlwall's law (McGregor and Swales, 1985, 1986 and 1991; Bairam, 1988; Bairam and Dempster, 1991; MacCombie, 1989, 1992, 1997 and 1998-99; and Atesoglu, 1993, 1994 and 1995)

A new approach to balance-of-payments-constrained growth

The causes of an economy´s balance-of-payments constraint are a low absolute values of the price elasticities of foreign trade and/or the independence of relative from the balance-of-payments disequilibria. Thus, the impact of relative prices on the growth rate does not hinder the effect of the balance-of-payments constraint. Consequently, this hypothesis cannot be tested through the degree of correlation between actual and Thirlwall´s Law rate of growth.

In fact, the main difference between the neoclassical approach to growth and the Keynesian-oriented balance-of-payments constraint hypothesis is the variable by means of which the balance-of-payments is achieved. Let us stress this fact by showing the dynamic version of the balance-of-payments equilibrium equation, which includes the exports and imports functions as indicated in equation (2):

$$\dot{y}\pi = (1+\gamma+\eta)(\dot{p}-\dot{p}^*)+\varepsilon(\dot{y}^*) \tag{6}$$

To simplify, we can consider the case where the foreign income remains constant. For this equation to hold when there is a trade balance deficit, either relative prices or income, or both, must decrease. This is the fundamental question: Which variable changes in the presence of a trade balance disequilibrium? In other words, which is the endogenous variable? According to neoclassical theory, adjustment occurs through changes in relative prices, while in Keynesian theory this role is mainly played by income. Consequently, the equations that should be tested in order to identify the correct approach to growth are:

$$\dot{y} = \alpha_1(x-m+p-p^*) \tag{7}$$

The meaning of equation (7) is that income changes when the trade balance is not in equilibrium.

2. THE MODEL

We use continuous time models because they have several attractive properties. These types of models are small and thus easy to manipulate analytically, which represent advantages over the large macro-econometric models where the properties of the model are investigated using numerical simulations. A continuous time model may also allow a more satisfactory treatment of distributed lag processes. An additional advantage is that these models allow for a better treatment of mixed flow-stock variables usually present in macro-econometric models. They take into account the fact that a flow variable is not measured instantaneously and that what one observes is in fact its integral over a certain period. Lastly, these models in principle ought to have an equilibrium, but it is important to note that this does not mean that the model is in this kind of equilibrium or that the equilibrium is necessarily stable. Therefore, the model can be solved for the actual paths, which may or may not be the equilibrium path.

The instrument to get that information is a mathematical model. The model is in continuous time[1] and includes five equations of equilibrium; the coefficient in each of them measures the speed of adjustment of the real value of the variable towards its equilibrium value. Furthermore, it is composed by five linearised equations that represent five dependant variables: income, exports, imports, technology and foreign direct investment. Every equation contains itself a set of main economic independent variables considered important in explaining the economic growth: prices of exports, prices of imports, internal level of prices, foreign income, human capital, domestic and foreign Research & Development Investment, capital stock, taxes rate, interest rate, single market effect, stability in labor market, infrastructures, etc. The parameters will render the values of elasticities of each variable in relation with the dependant variable it is explaining. The model is developed as follows[2]:

1) Income equation

$$\dot{y} = \alpha_1 (x + z + px - m - pm) . \qquad (8)$$

2) Exports equation

$$\dot{x} = \alpha_2 (x^e - x) , \qquad (9)$$

$$x^e = a + \beta_1 (px - p^*) + \beta_2 y^* + \beta_3 TG + \beta_4 EU + \beta_5 FDI$$

3) Imports equation

$$\dot{m} = \alpha_3 (m^e - m) , \qquad (10)$$

$$m^e = b + \beta_6 (pm - p) + \beta_7 y + \beta_8 TG + \beta_9 EU + \beta_{10} FDI$$

[1] See Gandolfo (1981, 1996)

[2] All the variables are transformed into logarithms and the point over them is the derivative of that variable with respect to time, so it represents the rate of change of each variable

4) Technolgy equation

$$\dot{TG} = \alpha_4 (TG^e - TG), \tag{11}$$

$$TG^e = c + \beta_{11} R\&D + \beta_{12} R\&D^* + \beta_{13} HK + \beta_{14} FDI .$$

5) Foreign Direct Investment equation

$$F\dot{D}I = \alpha_5 (FDI^e - FDI), \tag{12}$$

$$FDI^e = d + \beta_{15}(T - T^*) + \beta_{16}(p - p^*) + \beta_{17} TG + \beta_{18}(r - r^*) + \beta_{19} HK$$
$$+ \beta_{20} EU + \beta_{21} SEA + \beta_{22} Y + \beta_{23} Infra + \beta_{24} labstab$$

6) Foreign capital stock equation (13)

$$\dot{K}^* = FDI - \delta K$$

Table 1. Meaning of variables

Variable	Meaning
Y	Income
X	Exports
M	Imports
P	Consumer Prices Index
Px	Prices of Exports
Pm	Prices of Imports
P*	Prices of exports in competitors countries
Z	Current transferences and direct investment net revenues Index
Y*	Foreign income
TG	Technology
FDI	Foreign Direct Investment
HK	Human capital
R&D	Research & Development Investment
R&D*	Foreign Research & Development Investment
K	Capital Stock
T	Tax rate
T*	Foreign tax rate
SEA	Single Market effect
R	Interest rate
R*	Foreign interest rate
Infra	Infrastructures
Labstab	Stability in labour market

Table 2. Meaning and expected sign of parameters

Parameter	Meaning	Sign
α_1	Adjustment speed of Income towards the compatible level of external equilibrium	+
α_2	Adjustment speed of Exports towards the equilibrium level	+
α_3	Adjustment speed of Imports towards the equilibrium level	+
α_4	Adjustment speed of Technology towards the equilibrium level	+
α_5	Adjustment speed of Foreign Direct Investment towards the equilibrium level	+
β_1	Price elasticity of exports	-
β_2	Income elasticity of exports	+
β_3	Technology elasticity of exports	+
β_4	Effect of EU on exports. Dummy	+

β_5	Foregin Direct Investment elasticity of exports	+
β_6	Price elasticity of imports	-
β_7	Income elasticity of imports	+
β_8	Technology elasticity of imports	-
β_9	Effect of EU on exports. Dummy	+
β_{10}	Foregin Direct Investment elasticity of imports	+
β_{11}	Irish Research & Development elasticity of technology	+
β_{12}	Foreign Research & Development elasticity of technology	+
β_{13}	Human capital elasticity of technology	+
β_{14}	Foregin Direct Investment elasticity of technology	+
β_{15}	Tax rate (differential) elasticity of FDI	-
β_{16}	Relative prices elasticity of FDI	-
β_{17}	Technology elasticity of FDI	+
β_{18}	Interest rate (differential) elasticity of FDI	-
β_{19}	Human capital elasticity of FDI	+
β_{20}	Joining the European Union effect on FDI	+
β_{21}	Single Market effect on FDI	+
β_{22}	Income elasticity of FDI	+
β_{23}	Infrastructures effect on FDI	+
β_{24}	Labour stability effect on FDI	+
a, b, c, d	Constants	

Interpretation of equations

Equation 8. Income adjustment

The hypothesis assumed in this equation is as follow: external equilibrium is reached by variations in income so that, given a surplus in the balance of payments, income would grow to raise up imports and turn back to external equilibrium. If, on the contrary, there is a negative balance of payments, income would go down taking with it imports and, finally, external equilibrium would be achieved. So, external sector appears to be the key element to explain the growth of the Irish economy, which is one of the basic hypothesis. However, on the other hand, said external equilibrium is defined as XPxZ=MPm, that is, variable Z is added to exports revenues. This variable is an index that represents alternative ways to exports to finance the external acquisition of goods and services; specifically, it could be both direct investment and net current transferences. The reason that an index is used, instead of directly include those variables, is to make the analytical treatment of income adjustment equation easier. That is, if we do not operate in this way, external equilibrium would be determined how:

PxX + I + T = MPm ,

Where I and T refer to direct investments and net current transferences, respectively. Given that in equation (1) all variables are expressed in logarithms. To convert this expression into logarithms would imply a less manageable formulation of equation (1). That is the reason that next change has been carried out:
PxX + I + T = PxZ

Where the logarithm of the right term is the one used in equation (1).

Equation (9). Exports adjustment

The current level of exports fixes its equilibrium following an speed represented by α_2, whose sign is supossed to be positive, suggesting that, if exports go over that equilibrium value, they would go down. At the same time, that level of exports depend on relative prices of external retails and competitors level of prices –both expressed in a common currency-, on foreign income, on the Joining the EU effect, on the technology and on FDI. The reason why this last variable is considered directly and not only through its effect on technology or prices is because a significant percentage of FDI is has been installed exclusively to export, therefore, this variable would be considering this direct effect coming from the raising in the production capability of Irish economy. It could be treated as an offer variable.

On the other hand, the inclusion of technology into the exports equation hides an important element; in an uni-sectorial economic system where there only exist an homogeneous commodity, it would not make sense to include it, given that the only way of increase or decrease competitivity is by variations in relative prices. So, the resultant effect of technological progress would be captured by prices elasticity. Nevertheless, once admitted the existence of qualitative differences and different commodities, the possibilities of competence are greater; this justify the inclusion of a variable that captures this fact. On the other hand, the exclusion of that variable could create important errors in the figure and sign of prices elasticity. So, the elasticity of prices should be negative. Así, la elasticidad precios debería ser negativa. However, the no-inclusion of the variable that captures the quality level of the offer could render an apparently positive elasticity of prices. The explanation is that, along a period time, prices are susceptible to go up, while, in parallel, there is an improvement in the quality-composition of the aggregate production of goods, giving place to a raise of demand and creating an apparently positive elasticity of prices; it would be a kind of explanation for the Kaldor´s Paradox: in some countries, raising of relative prices come accompanied of earnings in the market cuotas.

Equation 10. Imports adjustment

The structure of this equation is similar to the exports one. Purchases from outside fixes its equilibrium following a speed represented by α_3. Meanwhile, such equilibrium depends on the share of prices of imports over the internal consumer prices index, on the national income, on the technology, on the FDI and on the joining the EU.

Equation 11. Technology adjustment

The interpretation of the adjustment parameter is the habitual. On the other hand, technology is considered to be dependent on the national and foreign R&D (possible spill-over effect), on the FDI and on the human capital.

Equation 12. Foreign Direct Investment adjustmet

The interpretation of the adjustment parameter is, as well, the habitual. The reception of FDI is supposed to be dependent on the relative taxes, relative prices (showing the prices and costs factor when deciding to invest into Ireland. Wages or labor costs could be considered apart from prices of inputs and this variable apart from the exchange rate but it has been decided that the variable “prices” is a good proxy for all of them), on the effects of joining the EU and the entrance into the Single Market to measure the interest of Ireland as an springboard to export to Europe, on human capital, on infrastructures and technology. The differential of interest rate catches the macro-stability.

Equation 13. Growth of foreign capital

This equation represents the accumulation of the foreign capital stock. This expression comes defined as investment less depreciation, where δ represents the rate of depreciation. That expression is not defined in logarithmical terms so its conversion would be:

$$\dot{k}* = \frac{\dot{K}*}{K*} = \frac{FDI}{K*} - \delta = e^{fdi} e^{-k*} - \delta$$

as this equation is not lineal, it has been linearised around the mean value of the simple, that is:

$$\dot{k}* = \sigma + \varphi fdi - \varphi k$$

where $\sigma = \frac{e^{\overline{fdi}}}{e^{\overline{k*}}}(1 - \overline{fdi} + \overline{k*})$ and $\varphi = \frac{e^{\overline{fdi}}}{e^{\overline{k*}}}$, where the line over the variables represents the mean value.

Solving the model

To obtain the solution of the model in the steady-state, all the variables are supposed to grow at a constant rate, that is, the variables respond to an equation as:

$$Y_i = Y_0 e^{\lambda_i t}, \qquad X_i = X_0 e^{\lambda_i t}.$$

Substituing these expressions into the theoretical model and removing the Dummy variables:

$$\begin{aligned}\lambda_y = \alpha_1(&x_0 + \lambda_x t + z_0 + \lambda_z t + px_0 + \lambda_{px} t - \\ &- m_0 + \lambda_m t - pm_0 + \lambda_{pm} t)\end{aligned} \tag{14.1}$$

$$\begin{aligned}\lambda_x &= \alpha_2(a + \beta_1(px_0 + \lambda_{px} t - p*_0 - \lambda_{p*} t) + \\ &+ \beta_2(y*_0 + \lambda_{y*} t) + \beta_3(TG_0 + \lambda_{TG} t) + \beta_5(FDI_0 + \lambda_{FDI} t) - x_0 - \lambda_x t)\end{aligned} \tag{14.2}$$

$$\begin{aligned}\lambda_m &= \alpha_3(b + \beta_6(pm_0 + \lambda_{pm} t - p_0 - \lambda_p t) + \beta_7(y_0 + \lambda_y t) + \beta_8(TG_0 + \lambda_{TG} t) + \\ &+ \beta_{10}(FDI_0 + \lambda_{FDI} t) - m_0 - \lambda_m t)\end{aligned} \tag{14.3}$$

$$\begin{aligned}\lambda_{TG} &= \alpha_4(c + \beta_{11}(ID_0 + \lambda_{R\&D} t) + \beta_{12}(R\&D*_0 + \lambda_{R\&D*} t) + \beta_{13}(HK_0 + \lambda_{HK} t) + \\ &+ \beta_{14}(FDI_0 + \lambda_{FDI} t) - TG_0 - \lambda_{TG} t)\end{aligned} \tag{14.4}$$

$$\lambda_{FDI} = \alpha_5(d + \beta_{15}(T_0 + \lambda_T t - T*_0 - \lambda_{T*} t) + \beta_{16}(p_0 + \lambda_p t - p*_0 - \lambda_{p*} t) + \beta_{17}(TG_0 + \lambda_{TG} t) + \beta_{18}(r_0 + \lambda_r t - r*_0 - \lambda_{r*} t) + \beta_{19}(HK_0 + \lambda_{HK} t) + \beta_{22}(Y_0 + \lambda_Y t) + \beta_{23}(Infra_0 + \lambda_{\inf ra} t) + \beta_{24}(est_0 + \lambda_{est} t) - FDI_0 - \lambda_{FDI} t) \qquad (14.5)$$

This set of equations can be reordered as follow:

$$\lambda_y = \alpha_1(x_0 + z_0 + px_0 - m_0 - pm_0) + \alpha_1(\lambda_x + \lambda_z + \lambda_{px} - \lambda_m - \lambda_{pm})t \qquad (15.1)$$

$$\lambda_x = \alpha_2(a + \beta_1(px_0 - p*_0 + \beta_2 y*_0 + \beta_3 TG_0 + \beta_5 FDI_0 - x_0) + \alpha_2((\beta_1 \lambda_{px} - \lambda_{p*}) + \beta_2 \lambda_{y*} + \beta_3 \lambda_{TG} t + \beta_5 \lambda_{FDI} - \lambda_x)t \qquad (15.2)$$

$$\lambda_m = \alpha_3(b + \beta_6(pm_0 - p_0) + \beta_7 y_0 + \beta_8 TG_0 + \beta_{10} FDI_0 - m_0) + \alpha_3(\beta_6(\lambda_{pm} - \lambda_p) + \beta_7 \lambda_y + \beta_8 \lambda_{TG} + \beta_{10} \lambda_{FDI} - \lambda_m)t \qquad (15.3)$$

$$\lambda_{TG} = \alpha_4(c + \beta_{11} R\&D_0 + \beta_{12} R\&D*_0 + \beta_{13} HK_0 + \beta_{14} FDI_0 - TG_0) + \alpha_4(\beta_{11}\lambda_{ID} + \beta_{12}\lambda_{ID} + \beta_{13}\lambda_{HK} + \beta_{14}\lambda_{FDI} - \lambda_{TG})t \qquad (15.4)$$

$$\lambda_{FDI} = \alpha_5(d + \beta_{15}(T_0 - T*_0) + \beta_{16}(p_0 - p*_0) + \beta_{17} TG_0 + \beta_{18}(r_0 - r*_0) + \beta_{19} HK_0 + \beta_{22} Y_0 + \beta_{23} Infra_0 + \beta_{24} labstab_0 - FDI_0) + \alpha_5((\beta_{15}(\lambda_T t - \lambda_{T*}) + \beta_{16}(\lambda_p t - \lambda_{p*}) + \beta_{17}\lambda_{TG} + \beta_{18}(\lambda_r - \lambda_{r*}) + \beta_{19}\lambda_{HK} + \beta_{22}\lambda_Y + \beta_{23}\lambda_{\inf ra} + \beta_{24}\lambda_{est} - \lambda_{FDI})t \qquad (15.5)$$

and to get an independent solution from time, these following sub-systems must be fulfilled:

$$\lambda_y = \alpha_1(x_0 + z_0 + px_0 - m_0 - pm_0) \qquad (16.1)$$

$$\lambda_x = \alpha_2(a + \beta_1(px_0 - p*_0 + \beta_2 y*_0 + \beta_3 TG_0 + \beta_5 FDI_0 - x_0) \qquad (16.2)$$

$$\lambda_m = \alpha_3(b + \beta_6(pm_0 - p_0) + \beta_7 y_0 + \beta_8 TG_0 + \beta_{10} FDI_0 - m_0) + \alpha_3(\beta_6(\lambda_{pm} - \lambda_p) + \beta_7 \lambda_y + \beta_8 \lambda_{TG} + \beta_{10} \lambda_{FDI} - \lambda_m) \qquad (16.3)$$

$$\lambda_{TG} = \alpha_4(c + \beta_{11} R\&D_0 + \beta_{12} R\&D*_0 + \beta_{13} HK_0 + \beta_{14} FDI_0 - TG_0) \qquad (16.4)$$

$$\lambda_{FDI} = \alpha_5(d + \beta_{15}(T_0 - T*_0) + \beta_{16}(p_0 - p*_0) + \beta_{17} TG_0 + \beta_{18}(r_0 - r*_0) + \beta_{19} HK_0 + \beta_{22} Y_0 + \beta_{23} Infra_0 + \beta_{24} est_0 - FDI_0) \qquad (16.5)$$

and:

$$0 = \alpha_1(\lambda_x + \lambda_z + \lambda_{px} - \lambda_m - \lambda_{pm})t \qquad (17.1)$$

$$0 = \alpha_2(\beta_1(\lambda_{px} - \lambda_{p*}) + \beta_2\lambda_{y*} + \beta_3\lambda_{TG}t + \beta_5\lambda_{FDI} - \lambda_x)t \tag{17.2}$$

$$0 = \alpha_3(\beta_6(\lambda_{pm} - \lambda_p) + \beta_7\lambda_y + \beta_8\lambda_{TG} + \beta_{10}\lambda_{FDI} - \lambda_m)t \tag{17.3}$$

$$0 = \alpha_4(\beta_{11}\lambda_{R\&D} + \beta_{12}\lambda_{R\&D*} + \beta_{13}\lambda_{HK} + \beta_{14}\lambda_{FDI} - \lambda_{TG})t \tag{17.4}$$

$$\begin{aligned} 0 = {} & \alpha_5(\beta_{15}(\lambda_T - \lambda_{T*}) + \beta_{16}(\lambda_p - \lambda_{p*}) + \beta_{17}\lambda_{TG} + \beta_{18}(\lambda_r - \lambda_{r*}) + \beta_{19}\lambda_{HK} + \\ & + \beta_{22}\lambda_Y + \beta_{23}\lambda_{\inf ra} + \beta_{24}\lambda_{labstab} - \lambda_{FDI})t \end{aligned} \tag{17.5}$$

This last equations sub-system can be converted into:

$$0 = \lambda_x + \lambda_z + \lambda_{px} - \lambda_m - \lambda_{pm} \tag{18.1}$$

$$\lambda_x = \beta_1(\lambda_{px} - \lambda_{p*}) + \beta_2\lambda_{y*} + \beta_3\lambda_{TG}t + \beta_5\lambda_{FDI} \tag{18.2}$$

$$\lambda_m = \beta_6(\lambda_{pm} - \lambda_p) + \beta_7\lambda_y + \beta_8\lambda_{TG} + \beta_{10}\lambda_{FDI} \tag{18.3}$$

$$\lambda_{TG} = \beta_{11}\lambda_{R\&D} + \beta_{12}\lambda_{R\&D*}t + \beta_{13}\lambda_{HK} + \beta_{14}\lambda_{FDI} \tag{18.4}$$

$$\begin{aligned} \lambda_{FDI} = {} & \beta_{15}(\lambda_T t - \lambda_{T*}) + \beta_{16}(\lambda_p - \lambda_{p*}) + \beta_{17}\lambda_{TG} + \beta_{18}(\lambda_r - \lambda_{r*}) + \beta_{19}\lambda_{HK} + \\ & + \beta_{22}\lambda_Y + \beta_{23}\lambda_{\inf ra} + \beta_{24}\lambda_{labstab} - \lambda_{FDI} \end{aligned} \tag{18.5}$$

From that second sub-system of equations, solutions for the rates of growth of the endogenous variables in function of the exogenous ones in the steady-state can be obtained as follow:

$$\lambda_y = \frac{\beta_1\lambda_{PE} + \beta_2\lambda_{y*} + R(R\&D) + (R(\beta_{13} + \beta_{14}\beta_{19}) + (\beta_5 - \beta_{10})\beta_{19})\lambda_{HK} + (R\beta_{14} + \beta_5 - \beta_{10})S + \lambda_z + \lambda_{TT} - \beta_6\lambda_{pmp}}{\beta_7 - R\beta_{14}\beta_{22} - \beta_{22}(\beta_5 - \beta_{10})}$$

where:

$\lambda_{PE} = \lambda_{px} - \lambda_{p*}$; $\lambda_{pmp} = \lambda_{pm} - \lambda_p$; $\lambda_{TT} = \lambda_{px} - \lambda_{pm}$; $R\&D = \beta_{11}\lambda_{R\&D} + \beta_{12}\lambda_{R\&D*}$

$$S = \beta_{15}(\lambda_T - \lambda_{T*}) + \beta_{16}(\lambda_p - \lambda_{p*}) + \beta_{18}(\lambda_r - \lambda_{r*}) + \beta_{23}\inf ra + \beta_{24}labstab$$

$$R = \frac{\beta_3 - \beta_8 + \beta_{17}(\beta_5 - \beta_{10})}{1 - \beta_{14}\beta_{17}}$$

and the rest of endogenous variables can be obtained from these equations:

<u>Analysis of λ_y.</u>

- Denominator:

* β_7 :

captures the effect that says: any raising of GDP will be partially annulated because it is a raising in imports so, due to the requirement of keeping a balanced external trade, the said raising will be exclusively the one that ables the equilibrium.

* β_{22} $(\beta_5-\beta_{10})$:

as income grows (Y) the FDI grows as well. That, in ideal conditions, improves the balance of payments and make it possible a bigger growth of income.

* $R\beta_{14}\beta_{22}$.

$\beta_{14}\beta_{22}$: $\Delta\nabla y \rightarrow \Delta\nabla FDI(\beta_{22}) \rightarrow \Delta\nabla Tg\ (\beta_{14})$

$$R = \frac{\beta_3 - \beta_8 + \beta_{17}(\beta_5 - \beta_{10})}{1-\beta_{14}\beta_{17}}:$$

- Numerator: as $\Delta\nabla Tg \rightarrow \Delta\nabla X$ and M $(\beta_3-\beta_8)$. As well, as $\Delta\nabla Tg \rightarrow \Delta\nabla FDI$ $(\beta_{17}) \rightarrow \Delta\nabla X$ and M $(\beta_5-\beta_{10})$.

- Denominator. As $\Delta\nabla Tg \rightarrow \Delta\nabla FDI\ (\beta_{17}) \rightarrow \Delta\nabla Tg\ (\beta_{14})$

Therefore, denominator is the accumulative effect of technology, R&D. If it is stable, that denominator shall be between 0 and 1.

So, $R\beta_{14}\beta_{22}$ measures the impact on exports (X) and imports (M) of the oscillations in income directly by FDI and indirectly by technology.

- Numerator.

* Prices:

- $\beta_1\lambda_{PE}$.

Represents the effect on exports of variations in relative prices of exports.

- $(R\beta_{14}+\beta_5-\beta_{10})\beta_{16}(\lambda_P-\lambda_{P^*})$.

$\Delta\nabla(p\text{-}p^*) \rightarrow \Delta\nabla FDI\ (\beta_{16}) \rightarrow \Delta\nabla X$ and M (β_5-β_{10}) and as well $\Delta\nabla FDI \rightarrow \Delta\nabla Tg\ (\beta_{14})$ and through R $\rightarrow \Delta\nabla X$ y M.

- $-\beta_6(\lambda_{pm}-\lambda_p)$

Represents the effect on imports of variations in relative prices of imports.

- λ_{TT} .

Terms of trade: effect of the real exchange relation on the balance of payments.

* $\beta_2\lambda_{y*}$

Effect of foreign income on exports.

* R(R&D)

Represents the effect of R&D on exports and imports through technology and through the accumulative effect, technology-FDI (Tg-FDI).

*$(R(\beta_{13}+\beta_{14}\beta_{19})+(\beta_5-\beta_{10})\beta_{19})\lambda_{KH}$

Is the effect on exports and imports of variations in human capital through FDI (β_{19}) and Tg (β_{13}) taking into account the accumulative effect between these two variables mentioned above.

*$(R\beta_{14}+\beta_5-\beta_{10})S$

Represents the effect on exports and imports of variables container in S through FDI and indirectly through Tg by the accumulative effect shown in R.

* λ_Z

Captures the positive effect of the balance of payments for other revenues.

3. RESULTS OF ESTIMATION

Before showing the results of the estimation is worthy to precise: equation 13 does not contain any parameter to be estimated because both σ and φ are deterministic algebraic expressions. Nevertheless, that equation is only valid for the linearised values of the growth of foreign capital stock. That is the reason why these values have been used and not the real ones when estimating, dealing the equation 6 as an identity. The results for the significant variables are shown in table 1:

Table 3. Results of estimation Greece (t-ratios between brackets)

Adjustment parameters	Value	Speed of adjustment (in years) (1)
α_1	0.13 (2.36)	7.7
α_2	0.41 (1.89)	2.4
α_3	1.33 (3.08)	0.7
α_4	1.75 (2.36)	0.6
α_5	1.39 (3.61)	0.7
Elasticities	Value	Meaning
β_2	3.31 (10.54)	Income elasticity of exports
β_3	0.58 (2.67)	Technology elasticity of exports
β_4	0.49 (2.46)	Dummy Single Market.
β_5	0.17 (1.98)	Foregin Direct Investment elasticity of exports
β_6	-0.48 (2.71)	Price elasticity of imports
β_7	1.98 (3.43)	Income elasticity of imports
β_{12}	1.36 (1.98)	Foreign Research & Development elasticity of technology
β_{15}	-15.52 (5.55)	Tax rate (differential) elasticity of FDI
β_{16}	-1.46 (2.72)	Relative prices elasticity of FDI

(1) is $1/\alpha$ and represents the time that takes to eliminate 2/3 of the difference between the real value of the variable and its value of equilibrium.

Table 4. Results of estimation Ireland (t-ratios between brackets)

Adjustment parameters	Value	Speed of adjustment (in years) (1)
α_1	0.42 (2.36)	2.4
α_2	0.37 (2.22)	2.3
α_3	1.48 (3.92)	0.7
α_4	1.99 (3.36)	0.5
α_5	1.54 (4.62)	0.6
Elasticities	Value	Meaning
β_2	3.11 (11.53)	Income elasticity of exports
β_3	0.50 (2.60)	Technology elasticity of exports
β_4	0.43 (3.46)	Dummy Single Market.
β_5	0.13 (1.96)	Foregin Direct Investment elasticity of exports
β_6	-0.46 (3.71)	Price elasticity of imports
β_7	1.89 (38.39)	Income elasticity of imports
β_{12} (2)	1.48 (1.72)	Foreign Research & Development elasticity of technology
β_{15}	-18.82 (7.65)	Tax rate (differential) elasticity of FDI
β_{16}	-2.46 (2.71)	Relative prices elasticity of FDI

(1) is $1/\alpha$ and represents the time that takes to eliminate 2/3 of the difference between the real value of the variable and its value of equilibrium. (2) β_{12} is only significant at 90%

Table 5. Results of estimation Portugal (t-ratios between brackets)

Adjustment parameters	Value	Speed of adjustment (in years) (1)
α_1	0.10 (2.37)	10
α_2	0.39 (2.12)	2.5
α_3	1.28 (3.67)	0.8
α_4	1.93 (3.28)	0.5
α_5	1.44 (4.51)	0.7
Elasticities	Value	Meaning
β_2	3.01 (11.53)	Income elasticity of exports
β_3	0.56 (2.60)	Technology elasticity of exports

β_4	0.38 (3.46)	Dummy Single Market.
β_5	0.29 (1.96)	Foregin Direct Investment elasticity of exports
β_6	-0.39 (3.71)	Price elasticity of imports
β_7	1.92 (35.49)	Income elasticity of imports
β_{12}	1.44 (2.03)	Foreign Research & Development elasticity of technology
$\beta_{15\ (2)}$	-16.81 (4.66)	Tax rate (differential) elasticity of FDI
β_{16}	-3.43 (3.78)	Relative prices elasticity of FDI

(1) is $1/\alpha$ and represents the time that takes to eliminate 2/3 of the difference between the real value of the variable and its value of equilibrium. (2) β_{12} is only significant at 90%

Table 6. Results of estimation Spain (t-ratios between brackets)

Adjustment parameters	Value	Speed of adjustment (in years) (1)
α_1	0.28 (2.16)	3.57
α_2	0.44 (2.62)	2.3
α_3	1.83 (2.42)	0.5
α_4	1.75 (2.06)	0.6
α_5	1.37 (3.22)	0.73
Elasticities	Value	Meaning
β_2	3.11 (11.53)	Income elasticity of exports
β_3	0.50 (2.60)	Technology elasticity of exports
β_4	0.43 (3.46)	Dummy Single Market.
β_5	0.13 (1.96)	Foregin Direct Investment elasticity of exports
β_6	-0.46 (3.71)	Price elasticity of imports
β_7	1.89 (38.39)	Income elasticity of imports
β_{12}	1.48 (2.71)	Foreign Research & Development elasticity of technology
β_{15}	-18.82 (7.65)	Tax rate (differential) elasticity of FDI
$\beta_{16\ (2)}$	-2.46 (1.92)	Relative prices elasticity of FDI

(1) is $1/\alpha$ and represents the time that takes to eliminate 2/3 of the difference between the real value of the variable and its value of equilibrium. (2) β_{12} is only significant at 90%

As it can be seen, in every case, the adjustment parameters are significatives and have the suitable sign, that is, the variables fit their equilibrium level. Income is the slowest variable towards its equilibrium value. This fact entails that all the equations are individually stable.

With regard to the rest of parameters, signs of fitted and expected values match up in every case. The equilibrium level of exports equation would depend on the external income, on technology and on the foreign capital stock. Furthermore, the Dummy that represents the Single Market effect is significant. With regard to imports, only prices and income elasticity have resulted significant, but without the influence of technology or FDI. For technology, the only significant parameter has been foreign R&D investment and not the national one. This fact endorses even more the great importance of foreign firms for the peripheral economies. In other words, economies producing a set of goods to be exported with an outside-produced technology in theirselves, are more susceptible to grow faster. Finally, in the FDI equation, the only significant parameters are those for variables taxes and prices; both, taxes and prices, reflect the importance of costs when deciding to invest into these peripheral economies.

4. CONCLUSIONS: ACCOUNTING FOR GROWTH

Including the parameters from the previous tables this solution is got:

$$\lambda_y = \frac{3,11\lambda_{y*} + 0,75\lambda_{R\&D*} - 2,38(\lambda_t - \lambda_{t*}) - 0,31(\lambda_p - \lambda_{p*}) + \lambda_z + \lambda_{TT} + 0,46\lambda_{pmp}}{1,89}$$

and using the rates of growth of exogenous variables, the result of this estimation gives an estimated growth for the EU peripheral economies income during the period 1960-2014 of 187% as real income amount 163%, that is, the model overestimates the Irish growth in 14% along the fifty years or 0.25% per year, the Portuguese growth in 12% along the fifty years or 0.21% per year, the Spanish growth in 10% along the fifty years or 0.18% per year and the Greek growth in 12% along the fifty years or 0.21 per year. As it is seen in that equation, it is possible to separate the estimated growth by the contribution of each variable to the total. If we proceed as said and split the global result into that contribution considering two different periods (1960-2006 and 2006-2014 –the crisis-) the next results are obtained (table 7):

Table 7. Contribution of exogenous variables to the Greek growth (% over total growth)

Variable	1960-2014	1960-2006	2006-2014
Y*	90	100.7	74.8
R&D*	15.1	12.3	10
t-t*	7.7	-1.7	7
p-p*	-0.4	0.3	-1.9
Z	-0.7	1.3	-2.2
TT	-4.7	-4.4	3.3
PMP	-7	-8.4	-2.3

Table 8. Contribution of exogenous variables to the Irish growth (% over total growth)

Variable	1960-2014	1960-2006	2006-2014
Y*	88.2	100.7	61.1
R&D*	16.8	13.6	23.7
t-t*	7.3	-1.7	26.8
p-p*	-0.4	0.3	-1.9
Z	-0.7	0.0	-2.2
TT	-4.7	-4.4	-5.3
PMP	-6.5	-8.4	-2.3

Table 9. Contribution of exogenous variables to the Portuguese growth (% over total growth)

Variable	1960-2014	1960-2006	2006-2014
Y*	92.2	100.7	97.1
R&D*	12.8	11.9	11.7
t-t*	5.3	0.7	2.8
p-p*	-1.4	2.3	-1.9
Z	-1.7	-2.0	-2.2
TT	-2.7	-8.4	-4.3
PMP	-4.5	-4.4	-3.3

Table 10. Contribution of exogenous variables to the Spanish growth (% over total growth)

Variable	1960-2014	1960-2006	2006-2014
Y*	98.2	95.7	91.1
R&D*	8.8	11	8.7
t-t*	5.3	3.3	11.8
p-p*	-0.7	0.0	-2.3
Z	-0.4	-4.4	-2.1
TT	-6.5	0.3	-5.4
PMP	-4.7	-11	-1.9

As the tables show (7-10), for every period, the main explicative variable is the raising of foreign income, given that its growth is the engine of exports. However, its weight falls sharply in the last decade; although, during the first three decades it explains almost all the economic growth, during the last one its contribution falls sharply. Technological progress, fostered by foreign Research and Development (R&D*), explains 15.1%, 16.8%, 12.8% and 8.8% for Greece, Ireland, Portugal and Spain, respectively over the whole period, 1960-2014 and 10%, 23.7%, 11.7% and 8.7% for Greece, Ireland, Portugal and Spain, respectively over the economic crisis period, 2006-2014. Although the importance of fiscal reform in Irish miracle, this variable is less stable than technological ones as it can be seen in the contribution of both. The importance of fiscal reform is almost all focused on the last period and with an special features which main aim is to attract FDI and with an uncertain near future. The conclusion of all this factors is that, peripheral economic growth is due, over all, to external elements having to do with foreign income, FDI which, at the same time, has been appealed by low taxes (Ireland) and labor costs (Spain, Portugal and Greece). This entails a great risk for these economies, with the exception of Ireland, since internal technological progress, through both the national investment in R&D or in human capital, has not had a significative impact.

Over the last two decades many European governments have pursued ambitious research and development (R&D) policies with the aim of fostering innovation and economic growth in peripheral economies of Europe. The question is whether these policies are paying off. Arguments such as the need to reach a minimum threshold of research, the existence of important distance decay effects in the diffusion of technological spillovers, the presence of increasing returns to scale in R&D investments, or the unavailability of the necessary socio-economic conditions in these countries to generate innovation seem to cast doubts about the possible returns of these sort of policies. Throughout this paper we have attempted to identify the impact of R&D investment of the private, public, and higher education sectors on innovation. The influence of innovation and innovation growth on economic growth is then addressed. The results indicate that R&D investment, as a whole, and higher education R&D investment in peripheral economies of the EU, in particular, are positively associated with innovation. The existence and strength of this association are, however, contingent upon country-specific socio-economic characteristics, which affect the capacity of each economy to transform R&D investment into innovation and, eventually, innovation into technology and economic growth as it has been the Irish case. As far as the Greek, Portuguese and Spanish economies are concerned, the current strategy and therefore result is completely different: low levels of public and private spending on research and development and poor performance in the field of education have resulted in low technological levels and, finally, in poor rates of growth. On the other hand, the Irish economy has suffered a deep recession over the last years but the endowment of capital through FDI, technology, research and development (mainly generated and used by foreign firms) and skilled labor have allowed the Island to recover rapidly and to be positioned again in the select club of European fast-growth economies.

References

Alonso, J.A. y Garcimartín, C. (1998), "La restricción externa al crecimiento: nuevos enfoques". *Revista de Economía Aplicada*. Vol. VI, nº 16.

Alonso, J.A. y Garcimartín, C. (1998-99), A new approach to balance-of-payments-constrained growth model. *Journal of Postkeynesian Economics*. Vol. 21, NO. 2. pp. 259-282.

Atesoglu, H. S. (1993), "Balance of Payments Constrained Growth. Evidence from the United States". *Journal of Post Keynesian Economics*, vol. 15, nº 4, 507-514.

Atesoglu, H. S. (1994), "Balance of Payments Determined Growth in Germany". *Applied Economic Letters*, vol. 1, nº 6, 89-91.

Atesoglu, H. S. (1995), "An Explanation of the Slowdown in US Economic Growth", *Applied Economics Letters*, 2(4), 91-94.

Audretsch, D.B. and Feldman, M.P. (1996), R&D Spillovers and the geography of innovation and production, *American Economic Review, 86: 630-640*

Bairam, E. (1988), "Balance of payments, the Harrod foreign multiplier and economic growth: the European and North American experience". *Applied Economics*, December, nº 20(12), 1635-1642.

Bairam, E. and Dempster, G. (1991), "The Harrod Foreign Trade Multiplier and Economic Growth in Asian Countries". *Applied Economics*, November, vol. 23, n.º 11, 1719-1724.

Dosi, G. (1988), Sources, procedures and microeconomic effects of innovation. *Journal of Economic Literature 26: 1120 – 1171*

Gandolfo, G. (1981), "Qualitative Analysis and Econometric Estimation of Continuous Time Dynamic Models". North Holland.

Gandolfo, G. (1996), "Economic dynamics", Springer verlag.

Grossman, G.M., Helpman, E. (1994), Endogenous innovation in the theory of growth. *Journal of Economic Perspectives 8: 23-44*

Harrod, R. (1933). "International economics", Cambridge: Cambridge University Press.

Lichtenberg, F.R. (1992), R&D investment and international productivity differences. *NBER Working Paper N. 4161.*

McCombie, J. (1989), "Thirlwall´s" Law and balance of payments coinstrained growth – a comment on the debate. *Applied Economics*, 21(5): 611-29

McCombie, J. (1992), Thirlwall´s Law and balance of payments coinstrained growth: more on the debate. *Applied Economics,* 24(5): 493-512.

McCombie, J. (1997), Empiricis of the Balance-Of-Payments-Constrained Growth. *Journal of Post Keynesian Economics*, 9(3):345-75.

McCombie, J. (1998-99), In defense of Kaldor: a comment. *Journal of Post Keynesian Economics*, Vol. 21. NO. 2, pp. 353-361.

McGregor, P. G. and Swales, J. K. (1985) “Professor Thirlwall and Balance of Payments Constrained Growth”, *Applied Economics*, vol. 17, nº. 5, 17-32.

McGregor, P. G. and Swales, J. K. (1986), “Balance of Payments Constrained Growth: A Rejoinder to Professor Thirlwall”, *Applied Economics,* vol. 18, nº. 12, 1265-1274.

McGregor, P. G. and Swales, J. K. (1991) “Thirlwall´s Law and Balance of Payments Constrained Growth: Further Comment on the Debate”, *Applied Economics*, vol. 23, nº. 1, 9-20.

Romer, P. (1990). Endogenous technological change. *Journal of Political Economy 9805: S71-102*

Scherer, F.M. (1982). Inter industry technology flows in the United States. *Research Policy 11: 227- 245*

Smulder S., Van de Klundert. (1995). Imperfect competition, concentration and growth with firm-specific R&D. *European Economic Review* 39: 139-160

Thirlwall, A. (1979). Balance of Payments constraint as an explanation of International Growth Rate differences. Banca Nazionale del Lavoro Quarterly Review. 128(1): 45-53.

Thirlwall, A. (1997). Reflections on the concept of balance-of-payments-constrained growth. *Journal of Post Keynesian Economics,* Spring, 19(3): 377-85.

Thirlwall, A. (2001). The relation between the warranted growth rate, the natural rate and the balance of payments equilibrium growth rate. *Journal of Postkeynesian Economics,* vol. 24, No. 1. Pp. 81-88.

Thirlwall, A. (2003). Growth and Development, with special reference to developing economies. Palgrave Macmillan.

Trajtenberg M. (1990). Economic Analysis of product innovation. *Cambridge University Press. Cambridge*

Verspagen, B. (1997). European ‘Regional Clubs’: do they exist, and where are they heading. On economic and technological differences between European Regions. *Maastricht Economic Research Institute on Innovation and Technology MERIT, Mimeo*

Appendix. Data sources and description

Sources of data

National Statistics Office, OECD: OECD main indicators, AMECO (European Commision Annual Macroeconomic data), IMF, UNCTAD, World Bank, National banks (Reserves), European Central Bank

Definition of series

All the variables used in the model are expressed in constant prices, except Z; that variable is determined in Irish Pounds, Pesetas, Escudos and Dracmas (current prices). We use annual observations for the period from 1960 to 2014, and the series are defined as follows:

Y. GNP. Source: OECD

X. Exports of goods and services. Source: OECD.

M. Imports of goods and services. Source: OECD.

PX. Exports price deflator. Source: OECD.

PM. Imports price deflator. Source: OECD.

P. GNP price deflator. Source: OECD.

P*. Foreign price level. This index was built weighting consumer price indexes of the countries receiving Irish, Spanish, Greek and Portuguese exports, defined as:

$$P_j^* = \frac{\sum_i P_j w_{ij}}{tc_{ij}}$$

where $P_{j,}$ is the GDP deflator of country j, tc_j represents the exchange rate of Irish currency with respect to currency of country j and wj is the weight of country j as receptor of Irish exports averaged in periods of five years. Is necessary to be said that, for the calculation of these indicators, only member countries of OECD have been included. Source for prices: OECD; for the quotas, national statistics office; and for the exchange rate, IMF.

Z. Current transferences and direct investment net revenues Index. Source: for net current transferences, national statistics office; for foreign direct investment, UNCTAD.

Y*. Weighted foreign income; weighting: participation of each country in Irish, Spanish, Greek and Portuguese exports. Source: OECD.

TG. European Patent Office.

HK. Weighted index: population with secondary level studies, population with universitarian studies, science and engineering students as average on the total universitarian students and public spending as percentage of Gross National Income. The weighting is 0.35, 0.35, 0.15 y 0,15 respectively. Source: World Bank.

R&D. National investment in R&D of Irish, Spanish, Greek and Portuguese trade partners weighted by the rate of participation in Irish, Spanish, Greek and Portuguese imports. Source: investment in R&D, OECD; weighting, national statistics office.

T. Fiscal revenues as a percentage of Irish, Spanish, Greek and Portuguese GDP. Source: OECD.

T*. Fiscal revenues as a percentage of European Union GDP. Source: OECD and IMF.

R. Interest rate, public debt 10 years. Source: Irish, Spanish, Greek and Portuguese national banks, European Central Bank and AMECO.

R*. Average of public debt of the USA, UK and Germany, 10 years. Source: national banks (Reserves) in those three countries.

Inf. Stock of public capital. Source: Christophe Kamps (2003).

Labstab. Lost workdays due to labour disputes. Source: OECD.