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Abstract

This paper implements a panel approach to investigate the empirical relevance of 'Thirlwall's Law', which states that long-run growth must be consistent with balance of payments (BOP) equilibrium and is, thus, determined on the demand side. Building on ARDL modelling, mean-group and pooled mean-group estimation methods, we use annual data over the 1960-2010 years for a panel of 22 OECD countries and find significant support for the 'Law'. Next, we also explore empirically the hypothesis that the BOP-constrained growth rate (y_B) must equal the natural (or potential) rate of growth (y_N) and find that the data do not reject this hypothesis. Finally, we adopt a new approach, based on panel Granger-causality methods, to explore the direction of causality between y_B and y_N. The results indicate the existence of unidirectional long-run causality from y_B to y_N, thus reinforcing the view, embodied in the 'Law', that long-run growth is demand-determined and constrained by the BOP.

Keywords: Balance of payments, endogenous growth, panel cointegration, pooled mean-group estimation, panel Granger-causality

JEL codes: C23, F43, O40, O57

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The Balance of Payments Constrained Growth Rate and the Natural Rate of Growth: New empirical evidence

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1. Introduction

The emergence of large imbalances in the current accounts of many advanced economies in recent years has received much attention in the literature, renewing the debate regarding balance of payments adjustments and the concept of current-account sustainability. To the extent that they reflect the efficient inter-temporal allocation of capital, temporary current account deficits can be beneficial, but persistent deficits will lead to unsustainable balance of payments problems and, thus, to a default and/or a costly adjustment process via a fall in aggregate demand and growth. Thus, in the long-run, growth must be consistent with a sustainable current account and balance of payments (BOP) equilibrium.

Taking this as a starting point, Thirlwall (1979) proposes a model of BOP-constrained growth which produces a simple rule, known as "Thirlwall's Law", according to which the long-run growth rate consistent with BOP equilibrium is given by the ratio of exports growth to the income elasticity of demand for imports. The model is based on the assumption that relative Purchasing Power Parity (PPP) holds in the long-run, so that relative prices (measured in a common currency) do not change and BOP equilibrium is achieved via adjustments in the level of economic activity. The "Law" has been the subject of much empirical scrutiny, largely resulting in supporting evidence for the hypothesis that the BOP-constrained growth rate (y_B) performs well in predicting the actual average long-run growth rate ($\bar{y}$) (e.g. McCombie and Thirlwall, 2004, for a survey of studies). This outcome brings support to the Keynesian vision of economic growth as being demand-driven and indicates that, in the long run, trade flows are largely determined by non-price competitiveness, which reflects economies' structural characteristics and is captured by the income elasticities of demand for exports and imports.

Within the context of Post-Keynesian growth theory, the hypothesis that long-run growth is endogenous to demand is also at the basis of the approach advanced by León-Ledesma and Thirlwall (2002) to estimate the natural rate of growth (y_N). Defined by the sum of the growth rates of labour productivity and the labour force, y_N reflects an economy's potential growth rate and there is now a growing empirical literature showing that it responds endogenously to actual growth (y) (e.g. Dray and Thirlwall, 2011; Lanzafame, 2009, 2010; Libânio, 2009; Vogel, 2009).[1] Palley (2003) and Setterfield (2006) have analysed the relationship between y_B and y_N, presenting different theoretical arguments to support the view that the two rates must be equal (or very close) to each other. They argue that, as y_N represents the rate of growth of an economy's productive capacity, differences between y_B and y_N will inevitably lead to ever-increasing over-capacity utilisation (if $y_B > y_N$) or under-capacity utilisation (if $y_B < y_N$), unless there exist adjustment mechanisms operating to reconcile the two growth rates. Palley (2003) suggests that y_B adjusts to y_N via changes in the income elasticity of demand for imports, which is endogenous to the degree of capacity utilisation and rises with over-capacity utilisation. Thus, when growth is faster than y_N, the BOP-constrained growth rate falls towards y_N. This argument implies that, ultimately, it is supply-side constraints which determine long-run growth, thus reversing the theoretical approach underpinning Thirlwall's Law. Setterfield (2006), however, proposes an alternative, demand-driven

[1] For a recent survey on the theoretical and empirical evidence on the endogenous nature of the "natural" rate of growth, see León-Ledesma and Lanzafame (2010).

adjustment mechanism, via which it is y_N that converges to y_B. In his model, productivity growth is a positive function of the degree of capacity utilisation, so that when y_B is higher than y_N, the induced productivity growth raises the natural growth rate towards y_B. Setterfield's argument is consistent with the hypothesis that the natural rate of growth is endogenous to actual growth, as suggested by León-Ledesma and Thirlwall (2002). Intuitively, if the actual growth rate tends toward y_B and y_N is endogenous to it, then when $y_B > y_N$ the actual growth rate will tend to be higher than y_N too, raising the natural rate of growth towards y_B. Thus, empirically, the 'demand-based' argument that it is y_N which adjusts to y_B will be supported by evidence indicating that the actual growth rate tends toward y_B *and* y_N is endogenous to it. In practice, as recognised by Setterfield (2006), both supply- and demand-side forces may play a role and this reinforces the suggestion that, for a stable long-run equilibrium, y_B and y_N must be equal, or at least very close to each other.

Building on these insights, this paper investigates the empirical relevance of Thirlwall's Law for a sample of 22 OECD countries, using annual data over the period 1960-2010 and making a number of original contributions to the literature.[2] Firstly, we carry out the analysis of the BOP-constrained growth model within a panel framework while, to our knowledge, all previous studies in the literature are based on time-series methodologies. Given the nature of the "Law" as a general long-run limit to growth, the BOP-constrained growth model should and is usually assessed considering its average performance for a sample of countries. Contrary to time-series techniques, panel estimators allow focusing directly on the average performance of the model for the panel as a whole, rather than on single countries, thus providing more efficient estimates. Secondly, we make use of the Autoregressive Distributed Lag (ARDL) approach to panel cointegration, implemented via Mean Group (MG) and/or Pooled Mean Group (PMG) estimation as proposed by Pesaran *et al.* (1997, 1999). This methodology has a number of advantages over other panel cointegration

[2] Our dataset is an updated version of that used by Bagnai (2010). The data used in this paper were obtained from various OECD statistical databases, via the OECDiLibrary online service (http://www.oecd-ilibrary.org/).

methods (e.g. Pedroni, 1999; Westerlund, 2007), particularly in the case in which some of the series under analysis are (or may be) stationary. Thirdly, we use the approach proposed by León-Ledesma and Thirlwall (2002) to estimate the natural rate of growth and use these estimates to carry out parametric tests of the hypothesis that y_B equals y_N. Finally, using panel Granger-causality methods, we propose and implement a new approach to investigate empirically the direction of causality between y_B and y_N. As a robustness check on the ARDL-based analysis, we also carry out panel Granger-causality tests on the direction of (long-run) causality between y_B and y.

To preview our results, we find significant evidence supporting the BOP-constrained growth model and show that y_B performs well in predicting the actual long-run growth rate. Moreover, the panel estimates of y_B and y_N are very close to each other and the statistical tests performed do not reject the hypothesis of the equivalence between the two growth rates. Our analysis also indicates that y_N responds endogenously to the actual growth rate and, as mentioned, together with the evidence that y_B sets a long-run limit to growth this brings support to the Keynesian view that growth is, ultimately, demand-driven. More specifically, this outcome is consistent with a scenario in which the direction of causality runs from y_B to y to y_N. This hypothesis is confirmed by our panel Granger-causality approach, which provides clear evidence of unidirectional long-run causality from y_B to y, as well as from y_B to y_N.

The paper is organised as follows. The next section presents Thirlwall's (1979) model and illustrates the empirical tests of the Law advanced in the literature. Section 3 describes the ARDL modelling approach, as well as the MG and PMG estimators, while section 4 presents the results of the ARDL-based analysis. In section 5 we lay out the approach proposed by León-Ledesma and Thirlwall (2002), apply it to our panel of OECD countries to estimate y_N and then propose and carry out parametric tests of the hypothesis $y_B = y_N$. Section 6 illustrates and implements the panel Granger causality methodology. Finally, section 7 concludes.

2. The balance of payments constrained growth rate

Thirlwall's (1979) model is based on the following log-linear specifications for the import and export demand functions:

$$X_t = \left(\frac{P_{dt}}{P_{ft}}\right)^{\eta} Z^{\varepsilon} \tag{1}$$

$$M_t = \left(\frac{P_{dt}}{P_{ft}}\right)^{\theta} Y^{\pi} \tag{2}$$

where t indicates time, X, M, Y and Z are, respectively, the flows of exports, imports, domestic and world income (in real terms), P_d and P_f are domestic and foreign prices (measured in a common currency), $\eta < 0$ and $\theta > 0$ are price elasticities, while $\varepsilon > 0$ and $\pi > 0$ are, respectively, the income elasticities of exports and imports. In a growing economy, the long-run constraint of BOP equilibrium requires that exports and imports grow at the same rate. Log-linearising equations (1) and (2) and differentiating with respect to time, this equilibrium condition can be expressed as

$$\eta\left(p_{dt} - p_{ft}\right) + \varepsilon z_t = \theta\left(p_{dt} - p_{ft}\right) + \pi y_t \tag{3}$$

where lower-case letters denote the growth rates of the relevant variables. Assuming that relative prices expressed in a common currency do not change over time, equation (3) becomes

$$y_B = \frac{\varepsilon z_t}{\pi} \tag{4}$$

which can also be expressed as

$$y_B = \frac{x_t}{\pi} \tag{5}$$

The constraint to long-run growth takes the form of an upper limit defined by y_B, the growth rate of GDP which will equalise the rates of growth of exports and imports.

To avoid the potential problems involved in the estimation of the export function, the empirical relevance of the BOP-constrained growth model is usually investigated relying on the simple rule expressed in (5), which is known as "Thirlwall's Law". This depends crucially on the estimate of the income elasticity of demand for imports $(\hat{\pi})$, which can be retrieved from a standard aggregate import function, such as the log-linear specification

$$\log M_t = \gamma + \theta\left(\log P_{dt} - \log P_{ft}\right) + \pi \log Y_t + u_t \tag{6}$$

As the Law is concerned with long-run growth and the variables involved often display non-stationary behaviour, equation (6) is typically estimated via cointegration methods (e.g. Bairam, 1993; Alonso, 1999; Bagnai, 2010).

Four tests of the Law have been proposed and widely applied in the literature. Thirlwall (1979) relies on nonparametric methods, using the Spearman rank correlation coefficient to compare the average growth rate of countries $(\overline{y})$ with an estimate of the BOP-constrained growth rate given by $\hat{y}_B = \frac{\overline{x}}{\hat{\pi}}$, i.e. by the ratio of the average growth rate of exports $(\overline{x})$ to the estimate of the income elasticity of imports $(\hat{\pi})$. McGregor and Swales (1985) suggest a parametric test based on the cross-section estimation of

$$y_{Bi} = \alpha + \beta \overline{y}_i + u_i \tag{7}$$

where the subscript $i = 1.....N$ refers to the countries. Within this framework, the hypothesis that $y_B = \overline{y}$ is supported by the data if the null $H_0 : (\alpha, \beta)' = (0,1)'$ cannot be rejected at the usual significance levels. McCombie (1989) develops a test of the Law which is built on the "equilibrium income elasticity of imports". This is defined as the value of π which ensures that imports and exports are growing at the same rate and is, thus, given by $\pi' = \frac{\overline{x}}{\overline{y}}$. The hypothesis $H_0 : \widehat{\pi} = \pi'$, which is equivalent to testing $y_B = \overline{y}$, can be verified using the standard error of the estimated $\widehat{\pi}$. Finally, Alonso (1999) uses π' to calculate the implied growth rates of GDP consistent with BOP equilibrium and relies on cointegration methods to ascertain whether the resulting series shares a long-run trend with the actual growth rates, which would support the BOP-constrained growth model.

3. Econometric methodology: The ARDL approach, mean-group and pooled mean-group estimation

There is a large consensus in the literature on cointegration analysis as the most appropriate approach to study long-run relations in panels and a number of panel cointegration techniques are now available, such as those developed by Pedroni (1999, 2001, 2004) and Westerlund (2007). However, due to low power of the tests, panel cointegration tests can lead to potentially misleading results if a fraction of the series is stationary (Karlsson and Löthgren, 2000; Gutierrez, 2003). Thus, ascertaining the order of integration of the variables under analysis is an essential precondition to establish whether the use of panel cointegration tests is warranted.

A suitable alternative to panel cointegration tests is the use Mean Group (MG) and/or Pooled Mean Group (PMG) estimators within an Autoregressive Distributed Lag (ARDL) approach, as proposed by Pesaran *et al*. (1997, 1999). Both the MG and the PMG provide consistent estimates in a dynamic panel context even in the presence of potentially non-stationary regressors. Moreover, the ARDL approach allows the researcher to retrieve both the short-run and the long-run parameters of the model within the same estimation framework.

The general $ARDL\left(p, q_1, ..., q_k\right)$ panel specification can be formalised as follows

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{q} \delta_{ij}^{'} X_{i,t-j} + \mu_i + \varepsilon_{it} \tag{8}$$

where $i = 1, 2, ..., N$ indicates the cross-sections (groups); $t = 1, 2, ..., T$ the time periods; X_{it} is a $k \times 1$ vector of explanatory variables; δ_{ij} are the $k \times 1$ coefficient vectors; the coefficients of the lagged dependent variables, λ_{ij}, are scalars; μ_i represents the (group-specific) fixed effect. If the variables are I(1) and cointegrated, the short-run dynamics of the model will be influenced by any deviation from equilibrium, so that it is common to express (8) using the following error correction representation:

$$\Delta y_{it} = \phi_i \left(y_{i,t-1} - \beta_i^{'} X_{it} \right) + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij}^{*'} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \tag{9}$$

where $\phi_i = -\left(1 - \sum_{j=1}^{p} \lambda_{ij}\right)$, $\beta_i = \sum_{j=0}^{q} \delta_{ij} \Big/ \left(1 - \sum_k \lambda_{ik}\right)$, $\lambda_{ij}^{*} = -\sum_{m=j+1}^{p} \lambda_{im}$ with $j = 1, 2, ..., p-1$, $\delta_{ij}^{*} = -\sum_{m=j+1}^{q} \delta_{im}$ with $j = 1, 2, ..., q-1$. The parameter ϕ_i is the speed of adjustment of the error-correction process, which is significantly negative when the variables display reversion to a long-run equilibrium. The vectors $\beta_i^{'}$ and $\delta_{ij}^{*'}$ contain, respectively, the long-run and short-run parameters of the model. Lag selection in the ARDL model can be performed using single-equation estimation for each of the panel units. Removing serial correlation, the selection of an appropriate lag order also eliminates the problems arising from potential (regressor) endogeneity. However, particularly when the analysis of the short-run parameters is also of interest, it is recommended that all of the panel cross-sections be given the same lag order, chosen in accordance to the model and data limitations (Loayza and Ranciere, 2006).

If both N and T are sufficiently large, estimation of dynamic panel models, such as that formalised in (8), can be performed with several alternative approaches, which differ according to the degree of parameter heterogeneity allowed for. At one extreme, the pooled estimator imposes full-homogeneity of coefficients, while the fixed-effects estimator allows only the intercepts to differ across groups. Both of these estimators will produce inconsistent and misleading estimates if the coefficients are heterogeneous. At the other extreme, the fully heterogeneous-coefficient model imposes no cross-group parameter restrictions and is fitted separately for each group. The mean of the long- and short-run parameters across groups can, then, be estimated consistently by the simple arithmetic average of the coefficients. This is the MG estimator introduced by Pesaran and Smith (1995). Between the two extremes, the PMG estimator by Pesaran *et al*. (1999), combines both pooling and averaging, allowing the intercept and short-run coefficients (including the speed of adjustment) to differ across groups, but restricting the long-run slope coefficients to be the same across groups.

The choice between the MG and PMG estimators depends on the trade-off between consistency and efficiency. The PMG estimator imposes cross-group homogeneity of the long-run parameters, yielding consistent and efficient estimates when the restrictions are valid and, thus, dominating the heterogeneous MG estimator. If, however, the hypothesis of long-run parameter homogeneity is invalid, the PMG estimates are inconsistent while the MG estimator remains consistent. A standard Hausman test on the long-run parameter-homogeneity restriction can, thus, be used to choose the most appropriate between the MG and PMG estimators (Pesaran *et al*., 1999).

4. The ARDL approach: Results

We start our empirical analysis of the "Law" by assessing the stationarity properties of the variables in the import function, i.e. the logarithms of real imports (*LogM*), real GDP (*LogY*) and import relative prices (*LogRP*), using the classic univariate Augmented Dickey-Fuller (ADF) test. The optimal lag length selection was performed using the general-to-specific procedure suggested by Ng and Perron (1995). The results are reported in Table 1.

Table 1. ADF unit root tests

Country	*LogM*	*LogY*	*LogRP*
Australia	0.894	-1.714	1.044
Austria	-2.958*	-4.141**	-1.987
Belgium	-2.416	-4.772**	-1.525
Canada	-1.521	-3.938**	-1.183
Denmark	-0.942	-2.800^	-0.898
Finland	-0.788	-1.794	-1.306
France	-2.738^	-4.086**	-0.915
Greece	-3.172*	-4.899**	-0.528
Iceland	-1.736	-1.994	-3.446**
Ireland	-0.489	-0.557	-1.393
Italy	-3.050*	-6.701**	-1.570
Japan	-3.600**	-4.142**	-2.149
Mexico	-0.133	-3.854**	-1.942
Netherlands	-1.373	-2.643^	-1.768
New Zealand	-0.568	-0.801	-0.022
Portugal	-1.535	-3.066*	-0.390
Spain	-1.014	-1.975	-0.902
Sweden	-0.658	-1.494	-1.780
Switzerland	-1.367	-1.091	-1.523
Turkey	-0.186	-1.350	-2.338
UK	-0.292	-1.131	-0.669
US	-0.788	-2.485	-1.600

Notes: **, * and ^ indicate, respectively, significant at the 1%, 5% and 10% level

The ADF tests indicate that we are dealing with are a mix of I(1) and I(0) variables. But for a few exceptions, real imports and, particularly, relative import prices appear to be nonstationary, while there is evidence of stationarity for *LogY* in 11 out of 22 countries. As mentioned, in this context the use of panel cointegration tests would be inappropriate and likely to lead to misleading inference. Thus, we adopt the ARDL approach and make use of MG and PMG estimation methods.

As in most of the literature, we focus on “Thirlwall’s Law” as expressed in (5) and, thus, on the estimation of the import function formalised in (6). Following standard practice (e.g. Loayza and Ranciere, 2006), we impose a common lag-structure to all the panel cross-sections, estimating the model with 1 and 2 lags.[3] The results are reported in Table 2.

Table 2. Panel ARDL estimations of import function (6)

Estimator	MG	PMG	MG	PMG
LR Coefficient				
Lny	1.986**	1.780**	2.049**	1.787**
lnRP	0.156	0.634**	-0.022	0.568**
SR Coefficient				
EC	-0.296**	-0.159**	-0.251**	-0.133**
ΔLny	1.668**	1.803**	-1.739**	1.855**
ΔLnRP	0.005	-0.079	0.025	0.075
ΔLny(L1)	-	-	-0.124	-0.231^
ΔLnRP (L1)	-	-	0.121**	0.161**
ΔLny(L2)	-	-	-	-
ΔLnRP(L2)	-	-	-	-
Constant	-5.997**	-3.564**	-5.285**	-3.003**
<u>*McCombie Test*</u>				
Wald Test on $\hat{\pi} = \pi'$	0.23	3.42	0.31	1.46
p-value	0.63	0.06	0.57	0.23
Hausman statistic	2.59		1.30	
p-value	0.27		0.52	
$\overline{y}_B$	3.24		3.23	

Notes: **, * and ^ indicate, respectively, significant at the 1%, 5% and 10% level. L1 and L2 indicate lag of order 1 and 2.

All the estimations return significantly negative error-correction coefficients, providing strong support for the hypothesis that the variables share a significant long-run relation. The models

[3] Notice that the PMG estimator, which turns out to outperform the MG technique in most of our regressions, has been shown to be robust to the choice of lag order, as well as to outliers (e.g. Pesaran *et al.*,1999, Martínez-Zarzoso and Bengochea-Morancho, 2004).

with 1 and 2 lags return very similar results and in both cases the Hausman statistic indicates the PMG method as the appropriate estimator. The PMG estimate of the parameter of interest, the long-run income elasticity of demand for imports $\hat{\pi}$, is strongly significant and equal to about 1.8.[4,5] Moreover, in no case does the "McCombie Test" reject $H_0 : \hat{\pi} = \pi'$, i.e. the null hypothesis that, for the panel as a whole, the "equilibrium income elasticity of imports" is not statistically different from the estimate $\hat{\pi}$. As mentioned, this implies that the estimated average $\bar{y}_B$ is not statistically different from the mean growth rate of GDP $(\bar{y})$.[6] Overall, therefore, our analysis brings qualified support to the BOP-constrained growth model and the simple rule formalised in Thirlwall's Law.

5. The relationship between the BOP-constrained growth rate and the natural rate of growth

Adapted to a panel context, the estimation approach laid out by León-Ledesma and Thirlwall (2002) to pin down the value of the natural rate of growth can be based on the following specification of Okun's Law

$$\Delta\%U_{it} = \alpha_{i1} - \beta_1 \left(y_{it} \right) + \varepsilon_{it} \tag{10}$$

where the change in the percentage rate of unemployment at time *t*, i.e. $\Delta\%U_{it}$, is expressed as a linear function of the growth rate of output. Since the natural rate is defined as the sum of the

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4 We also estimated the ARDL(3,3,3) model, in which case the Hausman test turned out to be in favour of the MG estimator. Nonetheless, the results and, in particular, the estimated $\hat{\pi}$ were, again, very similar to those reported in Table 2.

5 As an additional robustness check, we performed the estimations including in the ARDL model a set of country-specific dummy variables to take account of the structural breaks detected by Bagnai (2010). The results, available upon request, did not change.

6 Over the years considered, for the panel as a whole, the equilibrium income elasticity of imports is equal to $\pi' = \frac{\bar{x}}{\bar{y}} = 1.83$, while the average growth rate is about 3.15 per cent.

growth rates of labour productivity and the labour force, unemployment will rise whenever the actual rate of growth falls below the natural rate, while it will fall when growth rises above y_N. That is, the natural rate of growth is that particular growth rate consistent with a non-changing unemployment rate. Thus, setting $\Delta\%U_{it} = 0$, for each country *i* the natural rate of growth can be retrieved from equation (10) as α_{i1}/β_1.

The use of this approach, however, is problematic. Because of the likely dependence of labour force participation on the growth rate of output and the effects of labour hoarding, the estimates of both α_{i1} and β_1 may be downward-biased. To overcome these drawbacks, León-Ledesma and Thirlwall (2002) propose reversing the dependent and independent variables in (10) and estimate

$$y_{it} = \alpha_{i2} - \beta_2\left(\Delta\%U_{it}\right) + \varepsilon_{it} \tag{11}$$

Setting $\Delta\%U_{it} = 0$, it can be seen that the individual intercepts $\left(\alpha_{i2}\right)$ from equation (11) will provide the country-specific estimates of the natural rate of growth. One can then proceed to testing formally the hypothesis that the natural rate of growth is endogenous to the actual growth rate using

$$y_{it} = \alpha_{i3} - \beta_3\left(\Delta\%U_{it}\right) + \lambda_3 D_i + \varepsilon_{it} \tag{12}$$

where

$$D_i = \begin{cases} 1 & y_{it} > y_{iN} \\ 0 & otherwise \end{cases} \tag{13}$$

The model in (12) results from the introduction of a dummy variable (D_i) in equation (11), to allow for a differential intercept whenever y_{it} is higher than the natural growth rate. The endogeneity hypothesis will be supported if λ_3, the coefficient of the intercept dummy D_i, is significantly different from zero.

Table 3. Panel fixed-effects estimations of models by León-Ledesma and Thirlwall (2002)

	Equation (11)	Equation (12)
Constant	3.018**	1.239**
$\Delta\%U_t$	-1.513**	-0.808**
D_i	-	3.274**
R^2	0.30	0.56
Wald Test on $\bar{y}_N = \bar{y}$	3.08	
p-value	0.08	
$\bar{y}_N$	3.02**	-
Slow-growth $\bar{y}_N$	-	1.24**
High-growth $\bar{y}_N$	-	4.51**

Notes: ** and * indicate, respectively, significant at the 1% and 5% level.

Relying on equation (11), we estimate the natural rate of growth for each country in our panel dataset via fixed-effects methods. The results, reported in Table 3, show that the average estimate $\bar{y}_N$ for the panel is 3.02 per cent, which is very close to the estimated average $\bar{y}_B$ of 3.24 per cent (Table 2). Moreover, the Wald test on $\bar{y}_N = \bar{y}$ cannot reject the null hypothesis that, for the panel as a whole, the estimated natural rate of growth is not significantly different from average growth over the years considered, indicating that growth tends towards $\overline{y}_N$ in the long-run. As $\overline{y}$ does not differ significantly from $\overline{y}_B$ either, this outcome is in line with the $y_B = y_N$ hypothesis.[7]

Estimation of equation (12) provides clear evidence that the natural rate of growth is endogenous to actual growth – the dummy variable D_i is strongly significant and signals that, on average, growth increases by about 3.27 percentage points when $y_t > y_N$. As mentioned, together with the evidence indicating that the actual growth rate tends to equal y_B in the long-run, this result brings support to the hypothesis advanced by Setterfield (2006) that the adjustment process between y_B and y_N is demand-driven. Specifically, the actual growth rate tends toward y_B and y_N adjusts endogenously to it, so that when $y_B > y_N$ the actual growth rate will rise above y_N too, thus raising the natural rate of growth towards y_B. It is the natural growth rate which adjusts to the BOP-constrained growth rate, not the other way round.

Next we explore these issues more formally and check the robustness of the ARDL-based results, proposing statistical tests of the hypothesis $y_N = y_B$ and investigating the direction of causality between the two growth rates via panel Granger-causality methods.

5.1. Testing the hypothesis $y_B = y_N$

Comparison between the country estimates of y_B and y_N, reported in Table 4, shows that the two rates are very close to each other, as well as to the average growth rate $\overline{y}$, not only for the panel as a whole but, in general, for the single countries too. However, obtaining statistical evidence of the apparent equivalence $y_B = y_N$ is problematic.

[7] However, as clarified in the next section, because of the (potential) correlation between the two growth rates, this evidence is not sufficient to prove that $\overline{y}_B$ is not *statistically* different from $\overline{y}_N$.

Table 4. Country estimates

Country	y_B	y_N	$\overline{y}$
Australia	3.04	3.43	3.49
Austria	3.29	2.63	2.82
Belgium	2.85	1.82	2.73
Canada	2.72	3.31	3.29
Denmark	2.65	2.07	2.16
Finland	3.05	3.20	2.99
France	3.13	3.63	2.95
Greece	3.44	2.50	3.59
Iceland	2.48	3.21	3.61
Ireland	4.80	4.67	4.34
Italy	3.00	2.76	2.66
Japan	4.27	4.20	4.10
Mexico	4.44	2.62	3.89
Netherlands	3.18	1.70	2.90
New Zealand	2.40	2.71	2.51
Portugal	3.19	2.66	3.52
Spain	3.95	3.22	3.67
Sweden	2.96	2.66	2.54
Switzerland	2.51	1.77	1.82
Turkey	4.45	4.45	4.38
UK	2.32	2.26	2.27
US	3.17	3.21	3.08

At the panel level, a parametric test of the hypothesis that the estimates of y_N and y_B are not statistically different from each other should be performed on $H_0 : \hat{y}_N = \frac{\overline{x}}{\hat{\pi}}$ and it requires an estimate of the covariance between $\hat{y}_N$ and $\hat{\pi}$, as theory suggests that the natural rate of growth and the BOP-constrained growth rate may be correlated. Given that $\hat{y}_N$ and $\hat{\pi}$ are retrieved from two different models and estimations, calculating their covariance is not straightforward.

As a way around this problem, we rely on the estimates of y_B and y_N for the individual countries in our panel to build two different tests. The first test is based on the following cross-section regression

$$y_{Ni} = \alpha + \beta y_{Bi} + \delta SD\left(y_{iN}\right) + \varepsilon_i \tag{14}$$

where the standard deviation of the actual growth rate from the natural growth rate, $\left(SD\left(y_{iN}\right)\right)$, is included on the right-hand side to control for the endogenous correlation between y_B and y_N. Since, as suggested by Palley (2003) and Setterfield (2006), it is deviations of the actual growth rate from y_N which may trigger endogenous changes in the BOP-constrained growth rate and/or the natural growth rate, controlling for the standard value of these deviations in a cross-section setting should do away with or, at least, alleviate the endogeneity problem.[8]

The second test relies on an instrumental-variable (IV) approach to deal with endogeneity and is based on

$$\overline{y}_i = \alpha + \beta y_{Bi} + \varepsilon_i \tag{15}$$

Formally, since the average growth rate is highly correlated with y_N, while y_B is exogenous with respect to it, we can avoid endogeneity issues using the average growth rate $\overline{y}$ as a proxy for y_N. This test is an inverted version of that proposed by McGregor and Swales (1985) where, to avoid the problems related to the endogeneity of actual growth with respect to the BOP-constrained growth rate, y_B is on the right-hand side and $\overline{y}$ is the dependent variable.

Table 5. Tests of the hypothesis $y_B = y_N$

	α	β	δ	F-test on $H_0 : \beta = 1$ (*p-value*)
$y_{Ni} = \alpha + \beta y_{Bi} + \delta SD\left(y_{iN}\right) + \varepsilon_i$	0.004	0.632*	0.184	2.59 (0.124)
$\overline{y}_i = \alpha + \beta y_{Bi} + \varepsilon_i$	0.005	0.807**	-	2.33 (0.142)

Notes: ** and * indicate, respectively, significant at the 1% and 5% level.

[8] We also estimated (14) using the simple standard deviation of the actual growth rate in place of $SD(y_{iN})$: The results did not change.

In both tests, the hypothesis of the equivalence between y_B and y_N will be supported if the null $H_0:(\alpha,\beta)'=(0,1)'$ cannot be rejected at the usual significance levels. The results, reported in Table 5, indicate that this is, indeed, the case. Specifically, neither test rejects the null hypothesis and, in both cases, the estimate of the parameter α is very small and insignificant while the coefficient β is significant but not significantly different from unity.[9, 10]

The results of these tests, therefore, are in favour of the hypothesis advanced by Palley (2003) and Setterfield (2006) regarding the equivalence between y_B and y_N. Next, we further explore the issue of whether it is the BOP-constrained growth rate which adjusts to the natural growth rate, or the other way round.

6. Panel Granger-causality analysis

In this section we examine the direction of causality between y_B and y_N, as well as between y_B and the actual growth rate, by means of panel Granger-causality tests. Briefly stated, our approach is based on the following intuition.

According to Thirlwall's Law, as formalised in (5), the BOP-constrained growth rate is equal to the ratio of exports growth to the income elasticity of demand for imports, which is a fixed parameter (i.e. $y_B = x_t/\pi$). Meanwhile, y_N is defined by the sum of the growth rates of labour productivity and the labour force, i.e. the growth rate of the labour force in efficiency units (lfe_t). Thus, the adjustment mechanisms between y_B and y_N can be investigated by examining the direction of long-run causality between x_t and lfe_t. More precisely, unidirectional long-run

[9] Out of the two tests, the IV approach developed with (15) seems more reliable, as the coefficient on $(SD(y_{iN}))$ in (14) turns out to be not significant, raising some doubts that this method controls for endogeneity appropriately.
[10] As a further robustness check, we also estimated an inverted version of (15) with y_B as dependent variable, i.e. the original formulation advanced by McGregor and Swales (1985). The results did not change.

causality running from x_t to lfe_t would indicate that it is y_N which adjusts to y_B, in line with the demand-driven process put forward by Setterfield (2006). On the contrary, evidence of unidirectional long-run Granger-causality from lfe_t to x_t would imply that y_B adjusts to y_N, as in the supply-side argument advanced by Palley (2003). Finally, bidirectional causality would be consistent with both supply- and demand-based mechanisms playing a role.

Similarly, Granger-causality methods can also be conveniently used to carry out an alternative test of the hypothesis that the actual growth rate is constrained by the BOP in the long-run. Specifically, this hypothesis will be supported if there is evidence of long-run causality from x_t to the actual growth rate. Thus, as a robustness check on the results of the ARDL-based analysis, we will also perform Granger-causality tests on the relation between x_t and y_t.

6.1. Panel Granger-causality: Methodology and results

Following Granger (1969), a stationary time series Y_t is said to 'Granger-cause' another stationary time series X_t if past values of Y_t significantly reduce the predictive error variance of X_t. Formally, such a Granger-causality test is usually performed via a regression of X_t on its own lags and lags of Y_t, so that the hypothesis that Y_t Granger-causes X_t cannot be rejected if the lags of Y_t are found to be jointly statistically significant.

More recently, Granger-causality methods have been variously adapted to and implemented in a panel context, mostly in relation to the determinants of economic growth (e.g. Attanasio *et al.*, 2000; Nair-Reichert and Weinhold, 2001; Kónya, 2006). In line with this literature, we adopt the approach put forward by Holtz-Eakin *et al.* (1988), basing our panel Granger-causality tests on the following panel vector autoregressive (VAR) model

$$X_{it} = \alpha_0 + \sum_{l=1}^{m} \beta_l X_{it-1} + \sum_{l=1}^{m} \delta_l Y_{it-1} + \mu_i + \varepsilon_{it} \tag{16}$$

where, as usual, $i = 1, 2, ..., N$ refers to the cross-sections (groups), $t = 1, 2, ..., T$ to the time periods and μ_i represents the (group-specific) fixed effect. As all the variables under analysis are stationary, the use of cointegration methods to capture long-run effects is not feasible in this case. [11] Thus, following standard practice in the literature, we average the data over five-year non-overlapping periods, in order to reduce the influence of short-run, cyclical effects and capture the long-run relations.[12] Because of data availability, Turkey is dropped from the panel and the time-period considered is limited to the 1970-2009 years. This results in a slightly unbalanced panel dataset with 21 cross-sections and a time dimension of 8 five-year average growth rates.

Estimation of the panel VAR model in (16) poses the well-known problems related to dynamic panel data (DPD) estimations. In particular, as firstly shown by Nickell (1981), the presence of individual effects makes Least Squares Dummy Variable (LSDV) estimates biased and inconsistent. A number of techniques have been proposed to correct for the 'Nickell bias' in DPD estimations and Monte Carlo simulations show that, in general, the choice of the most appropriate estimator depends on the size of the panel. However, the corrected LSDV (LSDVc) approach, proposed by Kiviet (1995, 1999) and adapted to unbalanced panels by Bruno (2005), has been shown to consistently outperform all available alternative estimators, including the commonly-used Generalised Method of Moments (GMM) techniques developed by Arellano and Bond (1991) and Blundell and Bond (1998) which, though consistent, are usually much less efficient (e.g. Judson and Owen, 1999; Bruno, 2005). Briefly stated, using the approximation of the Nickell bias derived by Kiviet (1995, 1999), the LSDVc approach removes the bias from the LSDV estimator to produce bias-corrected LSDV estimates, while exploiting the smaller variance of the LSDV method with

[11] The presence of a unit root in the growth rates x_t, lfe_t or y_t would imply explosive behaviour for the levels of these variables, which is completely at odds with economic theory, as well as empirical evidence.

[12] For a recent example of the use of this procedure within the panel Granger-causality context, see Hartwig (2010).

respect to the alternative DPD estimators.[13] This results in a very efficient procedure, particularly in small panels such as ours, so that we rely on the LSDVc method to carry out the panel Granger-causality tests.

The LSDVc estimation results are reported in Table 4. Optimal lag-length selection was performed with a general-to-simple procedure based on the Schwarz Information Criterion (SIC), starting with a maximum of 3 lags. In all cases, the optimal lag-length selected by the SIC turned out to be one. [14]

Table 4. Panel Granger-causality tests, LSDVc estimations

	Causality between y_B and y	
Dependent variable	x_{it}	y_{it}
$x_{it}(L1)$	0.220*	0.096*
$y_{it}(L1)$	0.058	0.373**
	Causality between y_B and y_N	
Dependent variable	x_{it}	lfe_{it}
$x_{it}(L1)$	0.366**	0.092*
$lfe_{it}(L1)$	-0.131	0.481**

Notes: ** and * indicate, respectively, significant at the 1% and 5% level.

As regards the relationship between the BOP-constrained growth rate and actual growth, we find significant evidence of panel Granger causality from exports growth to GDP growth, whereas the data reject the hypothesis that y_t causes x_t. This result of unidirectional (long-run) causality from x_t to y_t is entirely consistent with the hypothesis that it is the BOP-constrained growth rate

[13] To save space, the LSDVc technique is not described in detail here. The reader is referred to the relevant references.
[14] Use of the Akaike Information Criterion in place of the SBC did not change the results.

which sets the limit toward which the actual growth rate tends in the long-run, showing that the outcome of the ARDL-based analysis is robust.

Turning to the relationship between y_B and y_N, the panel Granger causality tests again point to the existence of unidirectional causality, running from y_B to y_N, as we find significant evidence that x_t Granger-causes lfe_t but not the other way round. This brings support to the view advanced by Setterfield (2006) that it is y_N which adjusts to y_B, thus supply which responds to demand, contrary to the opposite, supply-driven adjustment mechanism advanced by Palley (2003).

Overall, therefore, the outcome of the panel Granger-causality analysis gives robust support to the Keynesian notion of growth as primarily determined on the demand side, with BOP equilibrium acting as a long-run constraint and productive capacity adapting endogenously when actual growth is above the natural rate of growth.

7. Conclusions

This paper advocates and implements a panel approach to investigate the empirical relevance of 'Thirlwall's Law', making a number of contributions to the literature.

Building on ARDL modelling, mean-group and pooled mean-group estimation methods, we use annual data over the 1960-2010 years for a panel of 22 OECD countries to estimate the BOP-constrained growth rate and find that it is not statistically different from the average growth rate in the period. This provides significant support for the 'Law', indicating that growth must be consistent with BOP equilibrium in the long-run and is thus, ultimately, determined on the demand-side.

Next, following Palley (2003) and Setterfield (2006), we also explore empirically the hypothesis that y_B must equal the natural rate of growth y_N. Adopting the methodology developed by León-Ledesma and Thirlwall (2002), we estimate the natural rate of growth y_N for the countries in our panel dataset and find that the panel estimate of y_N is very close to the corresponding value of y_B. Moreover, in line with most of the literature, our results indicate that the natural rate of growth is endogenous to the actual growth rate, rising when $y_t > y_N$. Together with the evidence indicating that growth tends towards y_B in the long-run, this result strongly suggests that the equivalence between y_B and y_N stems from the adjustment of the natural rate of growth towards the BOP-constrained growth rate, not the other way round. This is in line with the demand-based argument proposed by Setterfield (2006) and consistent with a scenario in which the direction of causality runs from y_B to y to y_N.

In order to gain further insights on this process and check the robustness of the results, we first propose and implement parametric tests of the hypothesis $y_B = y_N$ and, subsequently, adopt a new approach, based on panel Granger-causality methods, to explore the direction of causality between y_B and y_N. We find that the data do not reject the hypothesis that y_B and y_N are, indeed, equal to each other, while the panel Granger-causality tests indicate the existence of unidirectional long-run causality from exports growth to the growth of the labour force in efficiency units. This implies that y_B Granger-causes y_N, rather than the opposite, thus supporting the view that long-run growth is determined on the demand side. Panel Granger-causality tests also provide a robustness check on the ARDL-based results, as we find significant evidence of unidirectional long-run causality from x_t to y_t, confirming that growth is constrained by y_B in the long-term.

Overall, the analysis carried out in this paper and the empirical evidence gathered reinforce the notion that the BOP represents the ultimate constraint on long-run growth and give remarkable support to the Keynesian vision of economic growth as being demand-driven.

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