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International transmission of medium-term technology cycles: Evidence from Spain as a recipient country

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International transmission of medium-term technology cycles: Evidence from Spain as a recipient country*

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Abstract

This paper documents stylized facts of international medium-term business cycles by exploring the pattern of comovement between a catching-up economy, Spain, and each of the obvious candidate countries to technological leadership of the 1950-2007 period, the U.S., France, Germany, Italy and the U.K. A remarkable feature of the international medium-term business cycle is the strong, positive lead displayed by the U.S. technology and terms of trade cycles over Spain's macroeconomic aggregates. The corresponding evidence when the counterpart to Spain is a large European economy is weaker, particularly in the case of Europe's medium-term technology cycles. Non-parametric tests results suggest that, over the medium-term cycle, a shift towards more economic integration may not necessarily be associated with increased international comovement.

Keywords: Medium-term business cycles; Stylized facts; International comovement; Technology diffusion.

JEL: E32; F41; F44; O3

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1. Introduction

Significant medium-frequency fluctuations in output growth have characterized the performance of several industrialized countries over the postwar period. The U.S. economy, undoubtedly the technological leader of the time, experienced very high output growth during the 1960s, a substantial slowdown in growth rates in the 1970s through to the early 1980s, and a return to high growth for much of the remaining period until the recession that started in late 2007 produced a large deterioration in growth figures. Spain, a clear technological laggard in 1950 and an economy subsequently shaped by the forces of catch-up and convergence, experienced a similar pattern of growth, but different timing, as downward swings in economic activity tended to appear once the U.S. economy had deteriorated[1]. Do medium-term oscillations whose origin is the technological leader transmit to follower countries? What are the main features of international medium-term business cycle comovement? Do we naturally observe, for example, stronger linkages in medium-term cycles when the leader and the follower countries are geographically closer or economically more integrated? In this paper, we attempt to address these questions by extensively examining the evidence on the medium-term business cycle comovement between a catching-up economy, namely Spain, and each of the obvious candidate countries to technological leadership of the 1950-2007 period, i.e. the U.S., France, Germany, Italy and the U.K. The ultimate goal of the paper is to inform business cycle theory and macroeconomic policy-making by gathering robust historical and cross-national evidence on the time series properties of open economy variables in industrialized countries. Several considerations present in the literature are useful to motivate our choice of countries and interpret the findings of the paper.

Spain was, in 1950, an impoverished country with a large, backward agricultural sector and a per capita income level at twenty-three percent of the U.S. one. Over the following decades, the economy benefited from an unprecedented international influx of capital, technology and ideas while the institutional and political change that started in the second half of the 1970s aligned the country with the political spirit and the economic vision of her European neighbors. Spain's relative per capita income multiplied by nearly two-and-a-half times from 1950 to 2007[2]. Not surprisingly, Spain has been considered a successful case of the European post-WWII experience of catch-up and cited as an example that economies of Central and Eastern Europe could aspire to imitate (Caselli and Tenreyro (2006)).

A close look at Spain's output data shows that the medium-frequency oscillations in economic growth that the country displayed over the postwar period are similar to the ones that Comin and Gertler (2006) identify for the U.S. economy. More particularly, Comin and Gertler (2006) point out that these fluctuations in U.S. output growth occurred over longer time horizons than standard business cycle analysis would allow for and put forward the idea that high-frequency shocks may persist into the medium-frequency thereby producing business cycles of greater length and volatility than conventionally analyzed. Thus, the medium-term business cycle considers that the medium-frequency and the high-frequency oscillations in output data are intimately related, being the former largely the result of high-frequency shocks. In a closed economy model, Comin and Gertler (2006) introduce a mechanism of persistence for high-frequency disturbances that is based on endogenous productivity dynamics. The endogenous productivity propagation mechanism is capable of generating strong medium-frequency oscillations in productivity data which are the result of nontechnological markup shocks at the high-frequency. Their aim is to provide a framework that is able to explain the strong comovement observed, over the medium-term, between output and productivity variables, namely the relative price of capital, TFP and R&D expenditure. Following the seminal work of Comin and Gertler (2006), the first contribution of this paper is to show that the main features of medium-term business cycles that these authors identify for the U.S. economy also characterize the performance of Spain, the representative European catching-up economy of the period. Furthermore, as our paper includes a variety of open economy variables, we establish several new facts of medium-term business cycles for the U.S. economy.

1: Comin and Gertler (2006) discuss the medium-term growth performance of the U.S. economy during the postwar years and Crafts and Toniolo (1996), Blanchard (1997), Temin (2002) and Eichengreen (2008), among others, provide similar evidence for economic growth in Europe and Japan since 1945.

2: The phases and proximate causes of long-term economic growth in Spain are explored in, e.g., Prados de la Escosura and Rosés (2009) and Chouliarakis and Correa-López (2009). Business cycle behavior at high-frequencies is studied in Dolado et al. (1993), Licandro and Puch (1997) and Ortega (1999).

The second contribution of this paper is to document the stylized features of international medium-term business cycle comovement. The representative study of international business cycle transmission is found in Backus et al. (1992, 1995), whose empirical findings on the cross-country correlations of macroeconomic aggregates became the stylized facts against which international business cycle models would be examined[3]. Recent developments in the literature of international business cycle comovement aim, among other things, to identify the dominant driving variables of international business cycles, assess the relative importance of world, regional and nation-specific factors for macroeconomic fluctuations, and study the effects of globalization on cross-national business cycle synchronization from a historical perspective (see, e.g., Kose et al. (2003, 2008), Artis (2008), Artis and Okubo (2009), Artis et al. (2011), Crucini et al. (2011), Mumtaz et al. (2011)). Amidst the application of different statistical methods, a common feature of the aforementioned literature is the use of the conventional definition of the business cycle that is based on the high-frequency component of macroeconomic time series. Very recently, Comin et al. (2009) study the relationship between the medium-term business cycles of the U.S. and Mexico in a two-country asymmetric DSGE model in which the transmission mechanisms rely on the procyclicality of both U.S. investment in exporting new technologies and U.S. FDI flows, the slow pace of international diffusion of new intermediate goods and the presence of investment adjustment costs in Mexico. Their aim is to capture the observed empirical regularity of Mexico's experiencing a larger and more persistent output response than the U.S. to a U.S. shock. Unlike previous studies on international business cycle transmission, the focus in Comin et al. (2009) has clearly shifted towards explaining comovement over medium-term cycles. To further document the features of international medium-term business cycle transmission, we study a sample of six industrialized economies and place one of them, namely Spain, as the reference catching-up country of the postwar period. Viewing the U.S. and the large economies of Europe as the technology leaders, we are particularly interested in the study of comovement between their respective technology variables, international relative prices and bilateral trade flows vis-à-vis Spain's macroeconomic aggregates. Since a productivity cycle may take time to transmit internationally, we explore the lead and lag structure of cross-country correlations over the medium-term. Exploiting the time dimension that the transmission of medium-term technology cycles may display relates to the literature on technology diffusion and postwar economic growth (see, e.g., Comin and Hobijn (2011)) in which an important factor driving output growth in Western Europe and Japan was the speed of technological transfers from the U.S. economy[4].

Our results suggest that Spain's medium-term cycle is very persistent and significantly more volatile than the conventional high-frequency cycle. Among a variety of other findings, the procyclicality of embodied and disembodied technical change, patent applications and the terms of trade constitutes a salient feature of the medium-term cycle in Spain. Regarding the international transmission of medium-term cycles, we show that the U.S. medium-term cycles of embodied and disembodied technical change, R&D expenditure, patent applications and the terms of trade are positively and strongly correlated with Spain's main macroeconomic aggregates[5]. Furthermore, the U.S. technology and international relative price cycles display, on average, a three-year lead over Spain's output cycle. The corresponding evidence when the counterpart to Spain is a large European economy is weaker, particularly in the case of Europe's medium-term technology cycles. The latter finding is somewhat surprising, and bears further consideration in the future, as one might have expected stronger technology transmission linkages between economies that are geographically closer and economically more integrated. On the other hand, and taking into account that the presence of additional transmission mechanisms cannot be ruled out, we find that a bilateral exports cycle from the U.S. to Spain is positively and contemporaneously correlated with Spain's imports, investment and output cycles and shows a positive two-year lead over Spain's consumption. This comovement pattern, together with the high cross-country correlation of embodied technical change and its procyclicality in Spain, lends support to the key mechanisms identified in Comin et al. (2009) for the transmission of U.S. shocks to developing economies. In addition, it is worth noting that the U.S. medium-term

3: Their relative ordering of the cross-country correlations of output, consumption and productivity between the U.S. and nine industrialized economies is known as the quantity anomaly. An anomaly since the empirical regularity failed to be met by the predictions of the baseline international real business cycle model (see, e.g., Backus et al. (1995), Baxter and Crucini (1995), Betts and Devereux (2000), Ambler et al. (2002, 2004) and Kehoe and Perri (2002)).

4: Comin and Hobijn (2011) argue that the differences in TFP dynamics recorded over the postwar period across Western Europe and Japan were partly due to the underlying differences observed in technology adoption patterns. During the postwar years, technology adoption costs fell amid an unprecedented wave of U.S. economic aid and technical assistance. The recipient countries that benefited the most experienced an acceleration in adoption rates, prompting faster catch-up growth.

5: Possibly with the exception of exports. Accordingly, these cross-correlations are negative for the medium-term cycles of the balance of trade and the current account.

cycle of the terms of trade displays a strong, positive lead over Spain's counterpart medium-term cycles, however we lack this kind of evidence for disembodied technical change, R&D expenditure and patent applications[6]. Finally, non-parametric tests results for Spain do not lend support to the view that, over the medium-term cycle, a shift towards more economic integration is necessarily associated with increased international comovement.

The rest of the paper is organized as follows. Section 2 briefly describes the business cycle decomposition and the data used. Section 3 explores the main features of the medium-term business cycle in Spain. Section 4 summarizes the evidence on international medium-term cycle transmission between the U.S. and Spain. Section 5 presents the counterpart evidence for European countries. Section 6 explores the effect of economic integration on the extent of international comovement. Finally, Section 7 concludes.

6: The corresponding results for Europe are more mixed.

2. Measurement and Data

We use the band-pass filter to extract the medium-term business cycle component of our economic data. Being a frequency domain detrending method, the band-pass filter is able to isolate components according to a predefined frequency range of oscillation (Christiano and Fitzgerald (1998))[7]. Thus, the business cycle component can be represented as a two-sided moving average of observed data with upper- and lower-bound frequencies of oscillation that, for the standard definition of the cycle with quarterly data, correspond to periodicities between 2 and 32 quarters. As the moving average representation is of infinite order, hence it would require an infinite number of observations, the literature has produced various approximations to estimate the business cycle component when data is limited. In particular, Baxter and King (1999) develop a fixed-length symmetric filter, i.e. one that specifies the number of leads and lags in the moving average, while Christiano and Fitzgerald (2003) provide a full-sample asymmetric filter in which the weights of leads and lags are allowed to differ depending upon the time series and each observation. To isolate the medium-term business cycle component, we apply the latter filtering method and, in doing so, we follow earlier work in Comin and Gertler (2006)[8].

More particularly, the medium-term business cycle is extracted as the sum of the high-frequency and the medium-frequency components of economic data. With annual data, the high-frequency component of the business cycle corresponds to frequencies between 2 and 8 years and the medium-frequency component corresponds to frequencies between 8 and 50 years. Comin and Gertler (2006) are the first to define this frequency range of oscillation for the business cycle component of the data. In practice, they incorporate the large cyclical variation that is typically recorded at the medium frequencies into the standard high-frequency measure of the business cycle. Thus, the medium-term cycle considers that the high- and the medium-frequency components of economic time series may not be orthogonal and, as a whole, it is concerned with fluctuations that last less than 50 years[9]. Finally, the low-frequency or trend component includes periodicities of 50 years and above, hence the identified trend is much smoother than standard decompositions of economic data would allow for. It is worth noting that the mapping of the filtered data into the time domain produces medium-term business cycles that last, on average, fifteen years for Spain and ten years for the U.S. economy.

Our data are annual and, for most of the variables, span from 1950 till 2007. The series are mostly nonstationary and thus are transformed into growth rates by taking log differences. The band pass filter is applied to the data in growth rates. Then, we cumulate the filtered data and demean the resulting series in order to obtain estimates of each frequency component in centered log levels. For those variables that are expressed as a ratio of GDP, namely those concerned with external balances, the filter is directly applied to the original, untransformed series.

As we have mentioned already, the sample of countries that we study includes the U.S., France, Germany, Italy, the U.K. and Spain. The variables of interest are divided into two sets[10]. The first set includes standard open economy business cycle aggregates such as output, hours, labor productivity, consumption, investment, exports, imports, the balance of trade and the current account. The second set encompasses other variables and intends to capture the medium-term oscillations that characterize measures of productivity, relative prices and bilateral trade flows. In particular, we include the quality-adjusted relative price of capital, TFP, private R&D spending, patent applications, the price mark-up, the terms of trade, the real effective exchange rate, bilateral real exchange rates, bilateral exports and bilateral imports. As in Comin and Gertler (2006), the quality-adjusted relative price of capital and TFP capture, respectively, embodied and disembodied technological change[11]. Patent applications is used as an alternative to R&D spending as it may reflect more accurately the potential pool of available technology, regardless of whether it is home-grown or foreign. The terms of trade are defined here as the ratio of the export price deflator and the import price deflator. A detailed discussion of data definitions, sources and construction can be found in the Appendix.

7: Alternatively, the Hodrick-Prescott filter relies on maximizing a criterion function to estimate a trend component where both, deviations of the data from trend and trend variation, are penalized. Yet, it is worth noting that the results presented next are robust to this choice of filters.
8: The basic Matlab code for the band-pass filter is available at www.aeaweb.org/aer/index.php.
9: For annual data, notice that the medium-term business cycle neglects any irregular component, i.e. fluctuations lasting less than two years.
10: The series are expressed in per working-age population (ages 15-64).
11: Thus, e.g., declines in the relative price of capital reflect positive, embodied technical change.

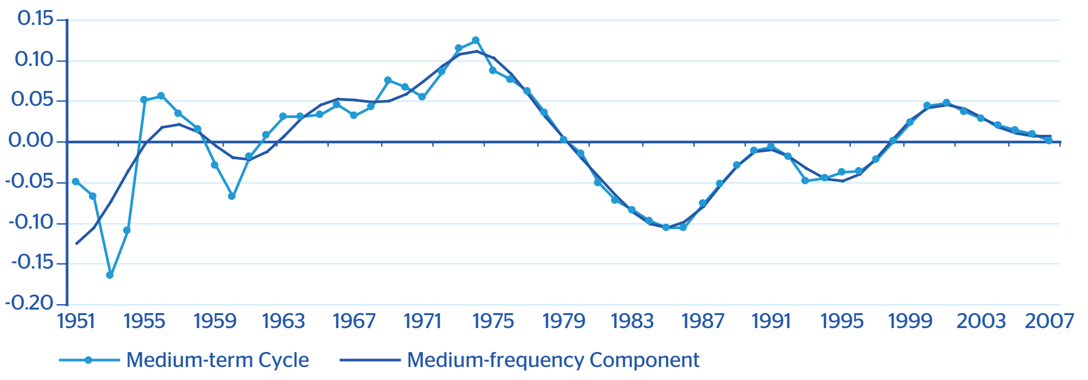
3. The medium-term business fluctuations in Spain

Previous studies of the Spanish business cycle have focused on the behavior of real macroeconomic variables and the ability of real business cycle models to reproduce the observed stylized facts. Dolado et al. (1993) were among the first to establish the main characteristics of the Spanish economy in the short run. These authors analyze the cyclical properties of a wide set of variables, including real, nominal and open economy indicators. Using quarterly data, they study the stability of such stylized features before and after 1980, and compare them with those of a set of OECD countries for the period 1970-1990. In the same spirit, Licandro and Puch (1997) characterize the Spanish business cycle for a slightly extended sample period and study the similarities of business cycles across Europe. Both papers have in common the use of the Hodrick-Prescott filter to detrend the time series. On the other hand, Ortega (1999) uses a band-pass filter to extract the high-frequency components of macroeconomic data and analyzes the relationship between real aggregate fluctuations in Spain and her European neighbors. Our work is related to Ortega (1999) in the use of the band-pass filter to estimate the business cycle yet it departs from it in one fundamental way. Namely, we employ the band-pass filter to study the high-frequency component, the medium-frequency component and the medium-term cycle of macroeconomic time series. Albeit the conventional high-frequency definition and the medium-term definition of the business cycle can complement each other, they have very distinct implications for business cycle theory.

Oscillations in the medium-term cycle, components and trend

The medium-term cycle of output per capita is represented by the line with circles in Figure 1 where the vertical axis measures the percent deviation, in unitary terms, of output per capita from trend. The medium-frequency component of the medium-term cycle is represented by the solid line and the standard measure of the business cycle is given by the vertical difference between the medium-term cycle and the medium-frequency component.

Figure 1
Output per Person 15-64 Spain

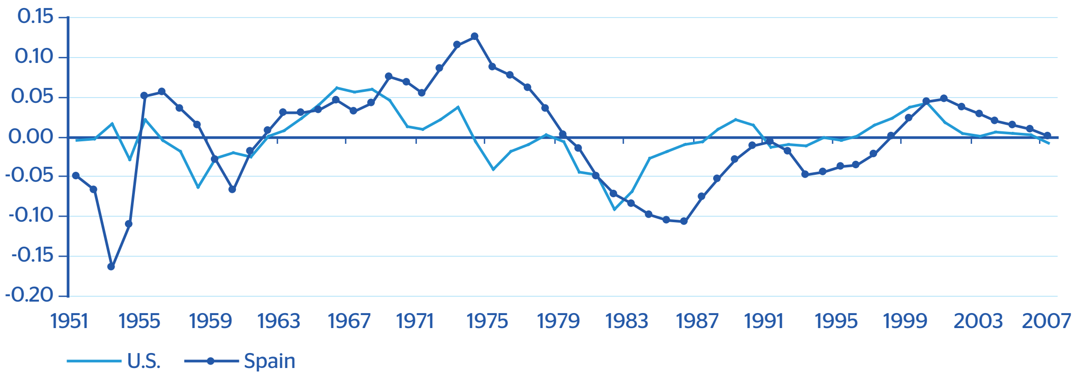


Source: Authors´ own calculations

The longer-term oscillations associated to the medium-term cycle are featured in Figure 1. Output moves upward relative to trend starting in the early 1960s through to the early 1970s. Subsequently, there is a sustained downward movement lasting over eleven years until the mid-1980s. A further upward swing commences on the first half of the 1990s through to the turn of the century. Finally, a downward swing in economic activity begins in the first half of the 2000s. Figure 1 also shows that the variation at the medium-frequency lies behind the persistent oscillations observed in the medium-term cycle, more so since the mid-1970s when the medium-term cycle becomes, to a large extent, a medium-frequency phenomenon. As the figure makes clear, the magnitude of the medium-term cycle is much larger than the magnitude of the standard high-frequency measure of the cycle.

Figure 2 plots the medium-term cycle in output per capita for the U.S. and Spain. The overall magnitude of the medium-term cycle appears larger for Spain than for the U.S. Over the upward swing of the 1960s, Spain's percentage rise in output relative to trend reaches 19 percent compared to a figure of 13 percent in the U.S. Similarly, the productivity slowdown of the 1970s is more protracted in Spain when the output fall relative to trend reaches 23 percent while the U.S. experiences a fall of about 15 percent. These cross-country differences in magnitude for the medium-term cycle do not seem to disappear in recent periods.

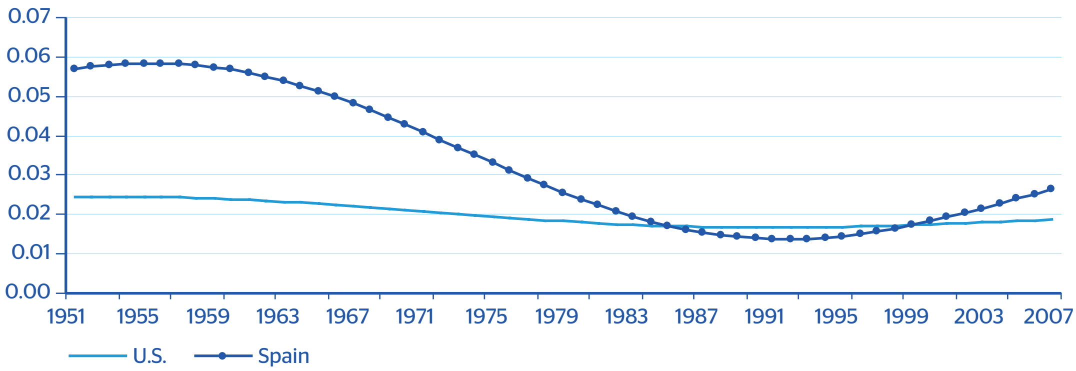
Figure 2
The Medium-term Cycle in Output per Person 15-64



Source: Authors´ own calculations

Figure 3 represents trend per capita output growth for the U.S. and Spain. For the U.S. economy, trend growth is very smooth and exhibits, overall, a moderate decline over the postwar period. Compared to the U.S., trend growth in Spain shows a fast convergence process over the third quarter of the twentieth century, a convergence process that is halted by the productivity slowdown of the 1970s, and a return to a moderate convergence pace since the late 1990s. As suggested by the figure, the variation in the trend growth rate relative to the overall variation in the growth rate is higher in Spain than in the U.S., as the ratio of the standard deviation of trend per capita output growth to the standard deviation of per capita output growth in the medium-term cycle is 0.5 and 0.1, respectively.

Figure 3
Trend Growth in Output per Person 15-64

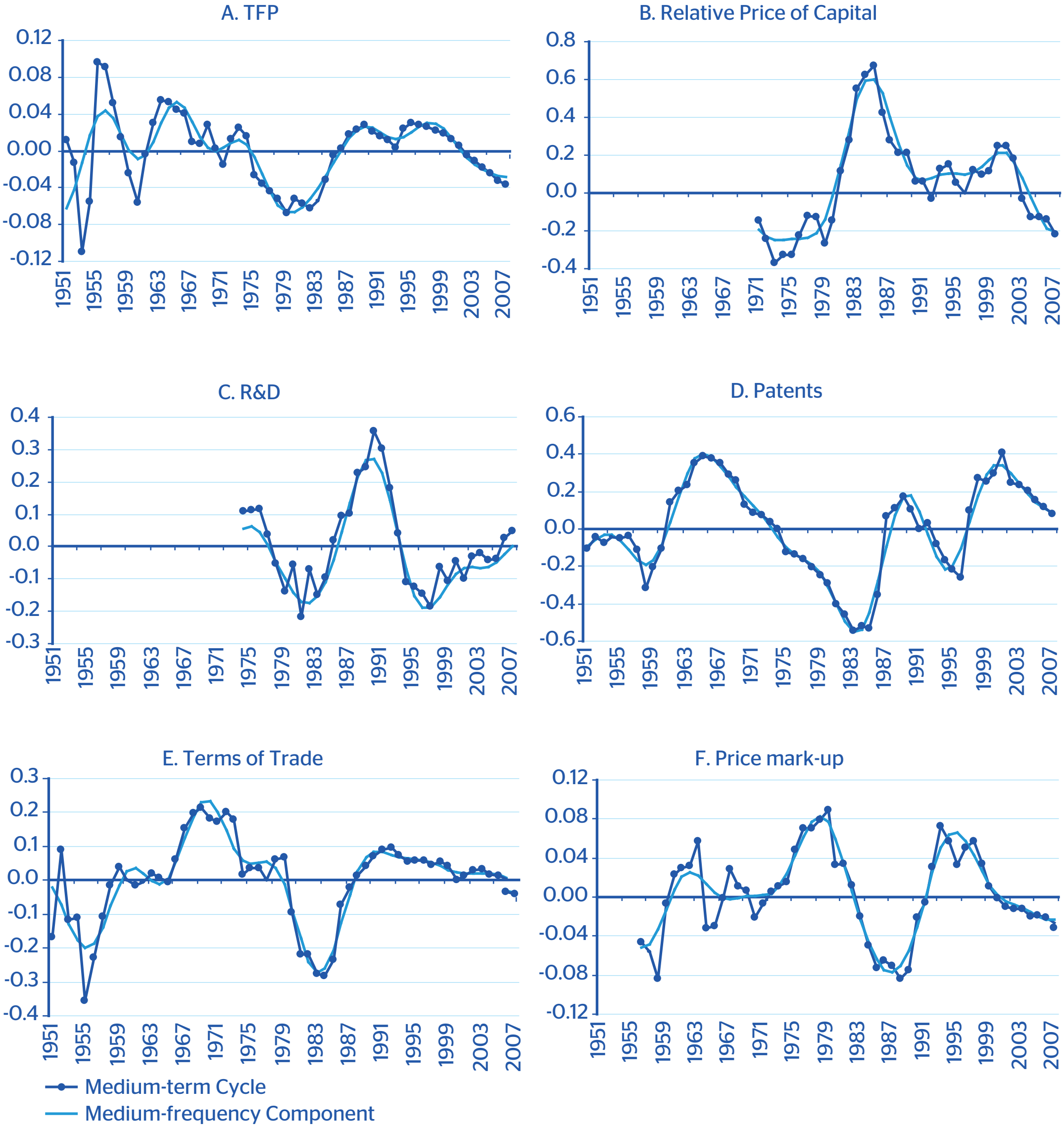


Source: Authors´ own calculations

To appreciate the behavior of the other variables, Figure 4 plots the Spanish series in the medium-term cycle and the corresponding medium-frequency component. As the panel A of the figure shows, the TFP series moves downward relative to trend during the productivity slowdown of the 1970s; TFP reverses course in the late-1970s through the late-1980s; stabilizes for most of the 1990s and, finally, begins a protracted downward swing that lasts until the end of the sample. Similarly, it is worth noting, in panel B, that the upward movement of the relative price of capital during the productivity slowdown of the 1970s was very pronounced and that the beginning of two downward swings relative to trend coincide, respectively, with Spain's joining the European

Economic Community (EEC) in the mid-1980s and with Spain's adoption of the euro in the turn of the century. Noticeably, for the last part of the sample, both types of technological change move in opposite directions.

Figure 4
The Medium-term Cycle in Spain´s Technology and Relative Prices



Source: Authors´ own calculations

A fairly similar pattern to TFP is exhibited by patent applications, the terms of trade and the price mark-up, the most notable exception being R&D expenditure that is on a recovery path relative to trend from the mid-1990s till 2007.

Stylized features of the medium-term cycle

Tables 1, 2 and 3 summarize the evidence necessary to characterize the medium-term business cycle fluctuations in Spain. More particularly, Table 1 reports the percent standard deviations of each variable over the medium-term cycle and both of its components. Below each standard deviation is the corresponding 95-percent bootstrap confidence interval[12]. Similarly, Table 2 reports the first-order autocorrelation coefficients and their associated confidence intervals. Finally,

12: We have typically used 1,000 random samples with replacement to obtain the results of the bootstrapping procedures reported throughout the analysis. Alternatively, we have found that using either 5,000 or 10,000 bootstrap samples delivers qualitatively similar results.

Table 3 presents evidence of comovement with output of the variables of interest for the U.S. and Spain over both, the medium-term cycle and the standard high-frequency measure of the cycle.

Table 1
Standard deviations: Annual frequencies

	Spain		
Standard variables	**Medium-term cycle 0-50**	**High-frequency component 0-8**	**Medium-frequency component 8-50**
GDP per capita	6.08	2.4	5.72
	(5.21,7.39)	(1.69,3.37)	(4.84,6.64)
Hours	6.59	0.71	6.54
	(5.75,7.64)	(0.60,0.95)	(5.71,7.48)
Labor productivity	3.83	2.41	3.02
	(3.13,5.11)	(1.72,3.38)	(2.55,3.58)
Consumption	6.43	1.62	6.36
	(5.37,7.72)	(1.09,2.35)	(5.35,7.47)
Investment	14.7	3.01	14.35
	(12.49,17.17)	(2.43,3.90)	(12.45,16.66)
Exports	17.63	6.35	16.28
	(14.91,21.07)	(5.10,8.95)	(13.79,19.46)
Imports	20.59	5.8	19.69
	(18.09,23.94)	(4.37,8.11)	(17.43,22.10)
Balance of trade/GDP	284.22	82.86	258.45
	(235.51,356.12)	(60.66,130.78)	(218.86,308.29)
Current account/GDP	215.36	114.82	161.14
	(172.50,277.17)	(94.52,145.90)	(139.89,193.35)
Other variables			
Relative price of capital	26.03	6.89	24.8
	(21.36,33.08)	(6.03,8.07)	(20.27,30.36)
TFP	3.94	2.48	3.11
	(3.29,4.94)	(1.74,3.48)	(2.64,3.67)
R&D	14	4	13.17
	(11.11,17.57)	(3.21,4.80)	(10.43,16.08)
Patents	24.8	5.48	24.14
	(21.55,29.25)	(4.42,7.09)	(20.79,28.42)
Terms of trade	12.55	4.82	11.58
	(10.12,15.55)	(3.72,6.66)	(9.63,13.82)
REER	11.95	5.43	10.2
	(9.69,15.64)	(4.31,7.53)	(8.39,12.01)
Price mark-up	4.44	1.61	4.05
	(3.80,5.20)	(1.25,2.12)	(3.41,4.80)

Source: Authors´ own calculations

The medium-term features that emerge from the tables are summarized next. First, we explore the results for the standard variables, then, we comment the findings on the set of other variables.

Main economic aggregates. Ouput per capita is very persistent (0.85), which is consistent with earlier results for the U.S. economy (Comin and Gertler (2006)). Investment is more than twice as volatile as output, very persistent and strongly procyclical. These features coincide with the high-frequency stylized facts for the U.S. economy detailed in Cooley and Prescott (1995). Consumption is very persistent too and strongly procyclical. It also shows slightly more volatility than output. This last result is also consistent with previous literature that documents the apparent contradiction with the life-cycle hypothesis[13]. Regarding open economy variables, both exports and imports are highly volatile, while imports are more persistent than exports. As in Ortega (1999), we find that exports are acyclical, or if anything weakly procyclical, and imports are strongly procyclical. Both facts help explain the countercyclical nature of the balance of trade, which is also highly volatile and very persistent. The current account displays high volatility, persistence and it is countercyclical[14].

Table 2
First-order autocorrelations: Annual frequencies

	Spain		
Standard variables	**Medium-term cycle 0-50**	**High-frequency component 0-8**	**Medium-frequency component 8-50**
GDP per capita	0.85	0.22	0.95
	(0.62,0.93)	(-0.40,0.76)	(0.93,0.97)
Hours	0.96	0.3	0.96
	(0.93,0.97)	(-0.02,0.54)	(0.94,0.98)
Labor productivity	0.68	0.26	0.93
	(0.20,0.87)	(-0.38,0.80)	(0.89,0.96)
Consumption	0.92	0.13	0.96
	(0.84,0.95)	(-0.27,0.63)	(0.93,0.97)
Investment	0.92	0.25	0.95
	(0.87,0.94)	(-0.06,0.50)	(0.92,0.97)
Exports	0.78	0.03	0.9
	(0.53,0.90)	(-0.29,0.39)	(0.83,0.94)
Imports	0.86	-0.33	0.96
	(0.78,0.91)	(-0.69,-0.07)	(0.94,0.98)
Balance of trade/GDP	0.92	0.45	0.94
	(0.86,0.95)	(0.18,0.81)	(0.91,0.96)
Current account/GDP	0.75	0.36	0.9
	(0.55,0.87)	(0.06,0.59)	(0.83,0.93)
Other variables			
Relative price of capital	0.89	0.23	0.95
	(0.81,0.94)	(-0.08,0.54)	(0.90,0.97)
TFP	0.68	0.26	0.92
	(0.30,0.86)	(-0.34,0.76)	(0.88,0.95)
R&D	0.82	-0.26	0.92
	(0.69,0.89)	(-0.57,0.09)	(0.85,0.96)
Patents	0.9	0.02	0.95
	(0.79,0.95)	(-0.30,0.32)	(0.91,0.97)
Terms of trade	0.8	-0.14	0.94
	(0.62,0.89)	(-0.61,0.27)	(0.91,0.96)
REER	0.75	-0.02	0.92
	(0.64,0.83)	(-0.31,0.31)	(0.87,0.95)
Price mark-up	0.82	0.06	0.94
	(0.65,0.90)	(-0.34,0.38)	(0.89,0.96)

Source: Authors´ own calculations

13: This is the explanation provided by Dolado et al. (1993) and Licandro and Puch (1997), for example. According to the life-cycle hypothesis, income fluctuates over time, and individuals should use savings to smooth consumption. In this sense, consumption is expected to be less volatile than output.
14: Backus et al. (1992) report evidence of a countercyclical balance of trade, over the high-frequency cycle, in eleven industrialized economies. Comin et al. (2009) find a countercyclical current account, over the medium-term cycle, in a developing economy.

Labor market. Over the medium-term cycle, hours are slightly more volatile than output, strongly persistent and clearly procyclical. Labor productivity, however, is half as volatile as output, persistent and, if anything, weakly procyclical. The results for hours are close to those in Ortega (1999) and the weak procyclicality of labor productivity is already noted in Dolado et al. (1993), albeit at the high-frequency with quarterly data.

Technology and innovation. The relative price of capital is more than four times as volatile as output, very persistent and strongly countercyclical[15]. TFP is half as volatile as output, persistent and procyclical. Patent applications and R&D spending are both highly volatile variables, more persistent than TFP, but differ in their comovement with output. In particular, patents are clearly procyclical whereas R&D is, if anything, very weakly procyclical[16]. It is worth noting the procyclicality of patents for both the U.S. and Spain which is even stronger than that of R&D spending.

Table 3

Contemporaneous correlations with GDP: Annual frequencies

	U.S.		Spain	
Standard variables	**Medium-term cycle 0-50**	**High-frequency component 0-8**	**Medium-term cycle 0-50**	**High-frequency component 0-8**
Hours	0.69	0.86	0.82	0.13
	(0.55,0.80)	(0.74,0.92)	(0.71,0.89)	(-0.04,0.27)
Labor productivity	0.5	0.45	0.17	0.96
	(0.32,0.67)	(0.26,0.63)	(-0.12,0.54)	(0.89,0.98)
Consumption	0.86	0.82	0.92	0.81
	(0.76,0.92)	(0.68,0.91)	(0.87,0.95)	(0.42,0.94)
Investment	0.79	0.9	0.89	0.67
	(0.70,0.87)	(0.83,0.95)	(0.81,0.93)	(0.48,0.78)
Exports	0.35	0.34	0.2	0.21
	(0.15,0.56)	(0.10,0.58)	(-0.05,0.43)	(-0.06,0.45)
Imports	0.76	0.84	0.75	0.2
	(0.61,0.85)	(0.72,0.89)	(0.56,0.87)	(-0.21,0.55)
Balance of trade/GDP	-0.29	-0.4	-0.57	0.08
	(-0.43,-0.15)	(-0.61,-0.16)	(-0.69,-0.37)	(-0.14,0.22)
Current account/GDP	-0.17	-0.33	-0.37	-0.2
	(-0.31,-0.00)	(-0.57,-0.12)	(-0.57,-0.15)	(-0.42,-0.03)
Other variables				
Relative price of capital	-0.71	-0.45	-0.79	-0.09
	(-0.83,-0.54)	(-0.66,-0.20)	(-0.89,-0.60)	(-0.37,0.26)
TFP	0.81	0.9	0.4	0.98
	(0.70,0.89)	(0.83,0.94)	(0.16,0.61)	(0.95,0.99)
R&D	0.32	0.37	0.11	-0.04
	(0.06,0.54)	(-0.04,0.61)	(-0.14,0.40)	(-0.34,0.26)
Patents	0.5	-0.13	0.5	0.14
	(0.34,0.65)	(-0.33,0.07)	(0.31,0.65)	(-0.00,0.31)
Terms of trade	0.63	0.19	0.47	-0.35
	(0.45,0.74)	(-0.05,0.41)	(0.15,0.66)	(-0.68,0.19)
REER	0.31	0.08	-0.17	0.03
	(0.11,0.50)	(-0.20,0.41)	(-0.40,0.08)	(-0.35,0.59)
Price mark-up	-0.46	-0.54	0.24	-0.15
	(-0.62,-0.25)	(-0.74,-0.29)	(-0.02,0.49)	(-0.39,0.24)

Source: Authors´ own calculations

15: Comin et al. (2009) also find a countercyclical relative price of capital in the Mexico-U.S. study.
16: Wälde and Woitek (2004) find evidence, over the high-frequency cycle, of the procyclicality of R&D expenditure in G7 countries for the 1970-2000 period.

International relative prices and the price mark-up. The terms of trade and the real effective exchange rate are roughly twice as volatile as output and very persistent, both regularities are in line with those stated in Backus et al. (1995), for U.S. high-frequency data, and in Dolado et al. (1993), for Spain during the period 1970:1-1990:4. However, both variables are less volatile than in previous studies considering data up to 1990, what suggests a great moderation in these variables. While the terms of trade is procyclical[17], the real effective exchange rate is, if anything, countercyclical, again in line with the literature that shows no clear consensus on the cyclicality of real exchange rates[18]. Finally, the price mark-up is less volatile than output, very persistent and weakly procyclical, which is consistent with the regularities identified in Galí et al. (2007) for the U.S. economy at the high-frequency.

Regarding medium versus high frequencies, Table 1 shows that, for each variable, the medium-term cycle is substantially more volatile than the standard high-frequency measure of the cycle. Moreover, greater volatility over the medium-term cycle is underpinned by the statistically significant volatility at the medium-frequency. Thus, for example, output per capita over the medium-term is nearly three times more volatile than over the high-frequency. For hours, the ratio of the standard deviation over the medium-term cycle to the standard deviation of the high-frequency component is 9.3 (6.59 to 0.71), indicating that the variation of total hours is very limited at high frequencies. In contrast to Dolado et al. (1993) and Ortega (1999), their well-established regularity of a more volatile consumption than output series is only present in the medium-frequency component of the medium-term cycle. Dolado et al. (1993) document this puzzle for the period 1970-1990 and argue that it may have been caused by changes in disposable income19. Our analysis indicates that this feature is not present at the high-frequency while it is a characteristic of the medium-term cycle for the period under consideration.

On the other hand, it is straightforward to conclude that, for each variable, the medium-term cycle is a highly persistent cycle. In contrast, the standard high-frequency measure of the cycle exhibits low, and largely not statistically different from zero, persistence in all variables. This is remarkable if we consider that conventional business cycle analysis relies on output persistence at the high-frequency. With long series of annual data, we find that strong persistence appears at the medium-frequency[20].

Finally, most of the macroeconomic aggregates are strongly procyclical except for the labor productivity and exports series that, albeit procyclical, have a low correlation coefficient and for the countercyclical nature of the balance of trade and the current account. Furthermore, to a varying degree, we can conclude that the procyclicality of embodied and disembodied technical change, patent applications and the terms of trade constitutes a salient feature of the medium-term cycle in Spain. Our findings also replicate earlier results in Comin and Gertler (2006) for the U.S. economy, to which we add the procyclicality of patent applications, the terms of trade and the real effective exchange rate.

Since the U.S. economy is naturally considered the technological leader of the postwar period, we next explore the cross-country medium-term business cycle features of the U.S.-Spain pair in an attempt to obtain evidence on the international transmission of the medium-term technology cycle.

17: Kehoe and Ruhl (2008) show that the terms of trade affect a country's real output and consumption in the sense that terms of trade deteriorations are associated with large contractions in output.
18: For example, Kollmann (2001) finds acyclical real exchange rates for the G3 countries.
19: Such changes are attributed to changes in taxes and transfers rather than liquidity constraints for the period 1970-1990.
20: Similar evidence for the U.S. economy is found in Comin and Gertler (2006).

4. The U.S. medium-term technology cycle as a source of domestic fluctuations

To obtain the stylized facts of the international medium-term business cycle for the U.S.-Spain pair, we start by calculating cross-correlations between U.S. macroeconomic aggregates and their counterparts in Spain. To allow for the possibility that medium-term business cycles do not transmit contemporaneously, we compute 10-year lead/lag correlation coefficients and their corresponding 95-percent bootstrap confidence intervals over the medium-term cycle and both of its frequency components. Table 4 reports the largest cross-correlation coefficient found for each pair of variables, the lead or lag year at which each largest coefficient is recorded, and the 95-percent bootstrap confidence interval of each statistic[21]. We attach a start symbol next to those cross-correlation coefficients for which the U.S. medium-term cycle is either contemporaneous to or has a lead over Spain's medium-term cycle[22].

Table 4
Pairwise cross-country correlations of macroeconomic aggregates

	Spain (y(t)) with U.S. (y(t+k))	
Standard variables	**Medium-term cycle**	**Medium-frequency component**
GDP per capita	0.64 (0.47,0.78) *	0.78 (0.66,0.87) *
	k=-3	k=-3
Hours	-0.71 (-0.80,-0.58)	-0.79 (-0.84,-0.69)
	k=4	k=4
Labor productivity	-0.32 (-0.55,-0.02)	-0.28 (-0.51,0.03)
	k=1	k=1
Consumption	0.78 (0.66,0.86) *	0.86 (0.78,0.91) *
	k=-3	k=-3
Investment	0.58 (0.36,0.74) *	0.68 (0.54,0.77) *
	k=-2	k=-3
Exports	-0.40 (-0.55,-0.19)	-0.45 (-0.58,-0.26)
	k=7	k=7
Imports	0.60 (0.39,0.76) *	0.68 (0.49,0.80) *
	k=-3	k=-2
Balance of trade/GDP	0.64 (0.43,0.80) *	0.61 (0.47,0.74) *
	k=-3	k=-3
Current account/GDP	0.62 (0.44,0.76) *	0.65 (0.48,0.78) *
	k=-4	k=-4

Source: Authors´ own calculations

The cross-correlations of output, consumption, investment, imports, the balance of trade and the current account are positive, very high, and significant, moreover, the U.S. cycle has, on average, a three-year lead over the Spanish cycle. The largest cross-correlation coefficient corresponds to consumption. On the other hand, hours, labor productivity and exports have a negative cross-correlation coefficient and the Spanish cycle shows a lead over the U.S. one in these variables. Table 4 shows that these results are driven by the cross-correlations at the medium-frequency. In general, these numbers are usually higher than those reported in the international business cycle literature at the high-frequency (see Backus et al. (1995) and Ambler et al. (2004), among others).

21: In order to economize space we do not report cross-correlation coefficients at the high-frequency. These are available from the authors upon request.
22: The results are presented in a similar way throughout the rest of the tables.

To assess the evidence regarding the international transmission of the medium-term technology cycle, Table 5 presents the cross-correlation coefficients between the U.S. technology variables and Spain's main macroeconomic aggregates over the medium-term cycle. The table also reports the cross-correlations between the terms of trade, bilateral trade flows and the bilateral real exchange rate of the U.S.-Spain pair and the main standard business cycle aggregates for Spain. Importantly, the first column of the table shows that the U.S. medium-term cycle of embodied and disembodied technical change, R&D expenditure, patent applications and the terms of trade is positively correlated with, highly significant, and leads Spain's medium-term cycle of output per capita. These cross-country correlation coefficients are very large and the result of the cross-correlations at the medium-frequency[23]. Regarding the relevant lead/lag relationship, the medium-term cycle of embodied technical change, TFP and patents in the U.S. exhibits a two-to-three year lead over the medium-term cycle of ouput per capita in Spain, while the terms of trade and the R&D U.S. cycles display longer leads.

Table 5

Cross-country correlations of other variables (U.S.) and macroeconomic aggregates (Spain)

	Spain (y(t)) with U.S. (y(t+k)) Medium-term cycle			
Standard variables (Spain)	**GDP**	**Hours**	**Consumption**	**Investment**
Other variables (U.S.)				
Relative price of capital	-0.81 (-0.89,-0.67) *	-0.93 (-0.95,-0.89) *	-0.88 (-0.92,-0.81) *	-0.87 (-0.92,-0.77) *
	k=-3	k=-3	k=-4	k=-2
TFP	0.69 (0.55,0.78) *	0.70 (0.57,0.78) *	0.77 (0.68,0.86) *	0.82 (0.72,0.89) *
	k=-2	k=-2	k=-2	k=-1
R&D	0.77 (0.63,0.88) *	0.69 (0.48,0.81) *	0.80 (0.63,0.89) *	0.81 (0.67,0.90) *
	k=-9	k=-10	k=-10	k=-8
Patents	0.77 (0.65,0.86) *	0.71 (0.53,0.82) *	0.70 (0.56,0.81) *	0.73 (0.59,0.84) *
	k=-2	k=-2	k=-3	k=-1
Terms of trade	0.81 (0.55,0.90) *	0.87 (0.80,0.92) *	0.90 (0.78,0.94) *	0.87 (0.78,0.92) *
	k=-5	k=-5	k=-5	k=-4
Bilateral exports	0.68 (0.41,0.83) *	0.56 (0.39,0.69) *	0.70 (0.50,0.80) *	0.68 (0.46,0.82) *
	k=0	k=-1	k=-2	k=0
Bilateral imports	0.64 (0.45,0.77) *	0.65 (0.48,0.76) *	0.79 (0.63,0.88) *	0.74 (0.56,0.85) *
	k=-3	k=-3	k=-3	k=-2
Bilateral real exchange rate	0.58 (0.40,0.73) *	0.64 (0.47,0.77) *	0.61 (0.44,0.73) *	0.76 (0.61,0.85) *
	k=-6	k=-6	k=-7	k=-6
Standard variables (Spain)	**Exports**	**Imports**	**Balance of trade/GDP**	**Current Account/GDP**
Other variables (U.S.)				
Relative price of capital	0.53 (0.26,0.73)	-0.81 (-0.88,-0.72) *	0.71 (0.56,0.82) *	0.48 (0.22,0.67) *
	k=9	k=-2	k=-2	k=-3
TFP	0.69 (0.53,0.78) *	0.81 (0.72,0.87) *	-0.61 (-0.73,-0.47) *	-0.40 (-0.58,-0.19) *
	k=-7	k=0	k=-1	k=-2
R&D	-0.52 (-0.71,-0.27)	0.84 (0.72,0.91) *	-0.68 (-0.79,-0.51) *	-0.30 (-0.51,-0.06) *
	k=2	k=-7	k=-6	k=-7
Patents	0.56 (0.41,0.71) *	0.64 (0.46,0.77) *	-0.71 (-0.81,-0.58) *	-0.37 (-0.59,-0.15) *
	k=-7	k=-1	k=0	k=0
Terms of trade	-0.50 (-0.67,-0.27)	0.85 (0.79,0.91) *	-0.66 (-0.78,-0.50) *	-0.46 (-0.64,-0.19) *
	k=5	k=-4	k=-4	k=-5
Bilateral exports	-0.56 (-0.71,-0.29)	0.83 (0.71,0.90) *	-0.48 (-0.62,-0.27)	-0.37 (-0.59,-0.15) *
	k=8	k=0	k=2	k=-7
Bilateral imports	0.43 (0.18,0.59) *	0.64 (0.45,0.77) *	0.58 (0.40,0.70) *	-0.40 (-0.62,-0.17) *
	k=-2	k=-2	k=-10	k=-4
Bilateral real exchange rate	-0.38 (-0.57,-0.18)	0.63 (0.46,0.75) *	-0.83 (-0.89,-0.73) *	-0.61 (-0.76,-0.46) *
	k=4	k=-6	k=-5	k=-6

Source: Authors´ own calculations

23: The corresponding statistics at both the high- and the medium-frequencies are available from the authors upon request.

The channel through which the U.S. medium-term technology cycle transmits may rely on bilateral trade linkages. The first column of Table 5 shows a large positive contemporaneous comovement of export flows from the U.S. to Spain with Spain's output per capita (0.68 [0.41, 0.83]), possibly indicating that once a technical improvement is embedded into U.S. exports it transmits fast to the output cycle of the recipient country. On the other hand, an exports cycle of Spanish goods to the U.S. correlates positively with and leads Spain's medium-term output cycle (0.64 [0.45, 0.77]). This comovement would be predicted by standard trade models in which a positive U.S. shock affects the demand for foreign goods. Similarly, the effect of this kind of shock may be present in the positive correlation coefficient of the bilateral real exchange rate (0.58 [0.40, 0.73]). The lead structure of the last two correlation coefficients may suggest that, as a result of a positive demand shock in the U.S., bilateral competitiveness gains pave the way to a positive cycle of Spanish exports to the U.S. which is then transmitted to the medium-term output cycle in Spain.

As it is fully appreciated in Table 5, a similar set of features to the ones identified for output emerge in the cross-country correlations of hours, consumption, investment and imports. Generally, the cross-correlation coefficients are very large and highly significant. It is worth noting that a bilateral exports cycle from the U.S. to Spain is positively and contemporaneously correlated with Spain's imports, investment and output cycles and shows a positive two-year lead over Spain's consumption. This comovement pattern, together with the evidence on embodied technical change presented above, resembles the key mechanism identified in Comin et al. (2009) whereby the transmission channel of U.S. shocks to Mexico occurs via changes in the flow of new U.S. technologies exported to Mexico, the associated movements in the relative price of Mexican capital and the subsequent impact on investment and consumption decisions in Mexico.

In contrast to the case of imports, only the U.S. TFP and patents cycles lead Spain's exports cycle and they do so with a seven-year lead as opposed to the two-year lead observed in the output cycle. Table 5 also shows that the medium-term U.S. cycle of embodied and disembodied technical change, R&D expenditure, patent applications and the terms of trade is negatively correlated with Spain's medium-term cycle of both the balance of trade and the current account. These cross-country correlation coefficients are generally large and exhibit a lead structure of the U.S. technological cycle of about two years on average.

To complete the evidence on the stylized facts of the medium-term business cycle for the U.S.-Spain pair, we finally obtain the pairwise cross-country correlations of technology variables and international relative prices. Table 6 presents statistics on comovements between other variables in the U.S. and their counterparts in Spain over the medium-term cycle and its medium-frequency component. Notably, the U.S. medium-term cycle of embodied technical change, the terms of trade and the real effective exchange rate correlates positively with and leads, in a highly significant way, its respective counterpart in Spain. However, this kind of evidence is lacking for TFP, R&D expenditure and patent applications.

Table 6
Pairwise cross-country correlations of other variables

	Spain (y(t)) with U.S. (y(t+k))			
Other variables	**Medium-term**		**Medium-frequency**	
Relative price of capital	0.74 (0.54,0.85)	*	0.83 (0.69,0.90)	*
	k=-3		k=-4	
TFP	-0.60 (-0.73,-0.42)	*	-0.65 (-0.76,-0.48)	*
	k=-10		k=-10	
R&D	-0.67 (-0.82,-0.38)	*	-0.71 (-0.88,-0.45)	*
	k=-10		k=-10	
Patents	0.82 (0.70,0.89)		0.91 (0.86,0.93)	
	k=2		k=2	
Terms of trade	0.72 (0.55,0.83)	*	0.81 (0.70,0.89)	*
	k=-2		k=-2	
REER	0.57 (0.38,0.71)	*	0.66 (0.54,0.74)	*
	k=-5		k=-5	

Source: Authors´ own calculations

Overall, the international medium-term business cycle features of the U.S.-Spain pair can be summarized as follows. First, the pairwise cross-country correlations of output, consumption, investment, imports, the balance of trade and the current account are positive, high and significant, moreover, they display, on average, a three-year lead of the U.S. cycle over Spain's cycle. Second, the U.S. medium-term cycles of embodied and disembodied technical change, R&D expenditure, patent applications and the terms of trade are positively and strongly correlated with and lead Spain's macroeconomic aggregates over the medium-term cycle, possibly with the exception of exports. Accordingly, these cross-correlations are negative for the medium-term cycles of the balance of trade and the current account. Third, the U.S. medium-term cycles of embodied technical change, the terms of trade and the real effective exchange rate are positively and strongly correlated with and lead Spain's counterpart medium-term cycles.

As the evidence indicates, these international medium-term business cycle features are the result of the cross-country correlations at the medium-frequency. This points out the necessity to further incorporate new mechanisms into medium-term business cycle models to be capable of explaining the strong lead displayed by the U.S. cycles of embodied and disembodied technical change, R&D expenditure, patent applications and the terms of trade over the output cycle of the recipient country.

Next, we assess whether the stylized facts of the U.S.-Spain medium-term business cycle carry over when the counterpart to Spain is a large European economy.

5. The medium-term technology cycle in Europe as a source of domestic fluctuations

The goal of this section is to examine whether the cross-country medium-term business cycle features described previously are representative of what happens between Spain and other major industrialized economies. We extend the sample to four large European countries, namely France, Germany, the U.K. and Italy, towards whom Spain has integrated economically over the last decades. Table 7 presents the cross-correlations between the macroeconomic aggregates of those individual European countries and their counterparts in Spain over the medium-term cycle[24].

Table 7
Pairwise cross-country correlations of macroeconomic aggregates

	Spain (y(t)) with individual countries (y(t+k)) Medium-term cycle			
Standard variables	**France**	**Germany**	**U.K.**	**Italy**
GDP per capita	0.76 (0.62,0.86)	0.71 (0.51,0.80) *	0.78 (0.65,0.86) *	0.49 (0.31,0.64)
	k=1	k=-1	k=-1	k=5
Hours	0.88 (0.79,0.92) *	0.50 (0.30,0.64) *	0.60 (0.35,0.75) *	0.26 (-0.00,0.50) *
	k=0	k=-9	k=-2	k=-10
Labor productivity	0.24 (-0.08,0.54)	0.68 (0.51,0.81)	0.24 (0.01,0.40) *	0.35 (0.16,0.57)
	k=4	k=5	k=-10	k=6
Consumption	0.85 (0.76,0.90)	0.75 (0.62,0.84) *	0.70 (0.51,0.82) *	0.63 (0.40,0.76) *
	k=1	k=0	k=-2	k=-2
Investment	0.89 (0.82,0.94) *	-0.61 (-0.75,-0.42)	0.90 (0.85,0.94) *	0.39 (0.14,0.57)
	k=0	k=10	k=-1	k=5
Exports	0.74 (0.62,0.82) *	-0.46 (-0.68,-0.14) *	0.61 (0.39,0.73) *	0.59 (0.38,0.74) *
	k=0	k=-9	k=0	k=-4
Imports	0.74 (0.61,0.81)	0.41 (0.12,0.60) *	0.61 (0.44,0.73) *	0.82 (0.74,0.88) *
	k=4	k=0	k=-1	k=-2
Balance of trade/GDP	0.58 (0.38,0.76) *	-0.42 (-0.70,-0.10) *	0.81 (0.70,0.89) *	0.43 (0.26,0.54) *
	k=0	k=0	k=-2	k=-1
Current account/GDP	0.45 (0.25,0.59) *	0.52 (0.34,0.66) *	0.46 (0.27,0.59) *	0.47 (0.24,0.60) *
	k=0	k=-10	k=-1	k=0

Source: Authors´ own calculations

The pairwise cross-correlations with France are all positive, high or very high and significant, except for the case of labor productivity that is neither high nor significant. In general, the medium-term cycle in France is contemporaneous to the medium-term cycle in Spain, with the exception of the imports cycle where Spain has a lead of four years. The cross-correlations with Germany of output, hours, labor productivity, consumption, imports and the current account are positive, high - albeit somewhat lower than the ones with France - and significant, at the other end, the cross-correlations of investment, exports and the balance of trade are negative, fairly high and significant. On average, the cross-country medium-term cycle features of the Germany-Spain pair exhibit a dynamic structure with longer leads and lags. The cross-correlations with the U.K. are all positive, high or very high and significant, except for the case of labor productivity that, once again, is neither high nor significant. The medium-term cycle in the U.K shows a one-to-two year lead over Spain's medium-term cycle. The cross-correlations with Italy are positive but, for the most part, not as high as the cross-correlations with other counterpart countries. As in the

24: The corresponding results at both the high- and the medium-frequencies are available from the authors upon request.

case of Germany, the cross-country medium-term cycle features of the Italy-Spain pair exhibit, on average, longer leads and lags. Finally, it is worth noting the countercyclical behavior of the balance of trade in the Germany-Spain pair which indicates that a positive medium-term cycle of the balance of trade in Germany is contemporaneous to a negative balance of trade cycle in Spain. In sharp contrast lies the positive and very large cross-correlation observed in the balance of trade of the U.K.-Spain pair, where the U.K. balance of trade cycle exhibits a two-year lead over Spain's counterpart[25]. Although the lead/lag structure is somewhat different, the qualitative results are consistent with those reported in Ortega (1999) for the main macroeconomic aggregates over the high-frequency.

The evidence of comovement between the medium-term technology cycle of each individual European country and Spain's medium-term cycle of output per capita is presented in Table 8. The medium-term cycles of embodied technical change of France, U.K. and Italy are positively correlated with, highly significant and have a one-to-two year lead over Spain's medium-term cycle of output per capita. In contrast, the medium-term cycles of TFP and R&D are, in general, negatively correlated with Spain's medium-term cycle of output per capita, moreover, they display long leads and lags. Finally, the medium-term cycle of patent applications and also the terms of trade of each European partner is positively correlated with, significant and, on average, leads Spain's medium-term output cycle.

Table 8

Cross-country correlations of other variables (Europe) with output per capita (Spain)

	Spain (y(t)) with individual countries (y(t+k)) Medium-term cycle			
Other variables	**France**	**Germany**	**U.K.**	**Italy**
Relative price of capital	-0.55 (-0.68,-0.41) *	0.39 (0.23,0.51) *	-0.76 (-0.88,-0.58) *	-0.81 (-0.91,-0.62) *
	k=-2	k=-1	k=-1	k=-1
TFP	-0.76 (-0.84,-0.66) *	-0.65 (-0.78,-0.47)	-0.75 (-0.84,-0.57) *	-0.54 (-0.70,-0.27) *
	k=-10	k=10	k=-10	k=-10
R&D	-0.81 (-0.89,-0.67) *	0.70 (0.35,0.87)	-0.57 (-0.77,-0.21)	-0.79 (-0.89,-0.59)
	k=5	k=10	k=3	k=3
Patents	0.69 (0.49,0.83) *	0.54 (0.32,0.70)	0.60 (0.46,0.72) *	0.64 (0.40,0.80) *
	k=-7	k=9	k=-2	k=-8
Terms of trade	0.76 (0.56,0.86) *	0.73 (0.57,0.84) *	0.71 (0.55,0.81) *	0.63 (0.40,0.78) *
	k=-2	k=-2	k=-8	k=-5
Bilateral exports	0.67 (0.53,0.76) *	0.78 (0.62,0.87) *	0.71 (0.58,0.82) *	0.66 (0.50,0.78) *
	k=-3	k=-3	k=-3	k=-3
Bilateral imports	-0.60 (-0.74,-0.42) *	-0.62 (-0.76,-0.35)	0.38 (0.14,0.58) *	-0.67 (-0.80,-0.53)
	k=-9	k=10	k=-4	k=10
Bilateral real exchange rate	0.57 (0.38,0.70) *	-0.51 (-0.71,-0.13)	0.67 (0.51,0.79) *	0.70 (0.53,0.82) *
	k=-10	k=10	k=-9	k=-7

Source: Authors´ own calculations

Trade linkages among European nations were substantially developed over the postwar period. As a result, one might expect to observe strong comovements of bilateral trade variables and Spain's output per capita, possibly suggesting that trade linkages have been a vehicle of transmission of international medium-term technology cycles in Europe. The cross-country coefficients reported in Table 8 show a large positive correlation of bilateral export flows from France, Germany, U.K. and Italy with Spain's output per capita. Furthermore, these bilateral exports coefficients display a three-year lead over Spain's medium-term output cycle. The latter

25: Regarding the pairwise cross-country correlations of output and consumption, notice that, over the medium-term cycle, the cross-correlations of consumption are higher than the cross-correlations of output for all the country-pairs considered in the paper - with the exception of the U.K. - i.e. the opposite ranking to the one that has traditionally emerged from the contemporaneous correlations at the high-frequency (see, e.g., Backus et al. (1995) and Ambler et al. (2004)).

may indicate that if a technological improvement is embodied in European exports it might take about three years to be felt in Spain's medium-term cycle of output per capita, in contrast to the contemporaneous transmission observed in U.S. data. Noticeably, the table also shows that only an exports cycle of Spanish goods to the U.K. correlates positively, albeit not very strongly, and leads Spain's medium-term output cycle while an exports cycle of Spanish goods to France, Germany and Italy correlates negatively.

Tables A.1 and A.2 in the Appendix confirm that the above set of features is present, for the most part, in the cross-country correlations of hours, consumption, investment, exports and imports. Similarly to the comparison with the U.S., albeit with a longer lag structure, we find that a bilateral exports cycle from any European country to Spain is positively correlated with Spain's imports, investment, output and consumption cycles, lending further support to the presence of the mechanism identified in Comin et al. (2009) for the international transmission of shocks originating in the technological leader. On the other hand, the results regarding the balance of trade and the current account are presented in Table A.3 of the Appendix. The table shows that a medium-term cycle of embodied technical change, patent applications and the terms of trade in the U.K. and Italy is negatively correlated with and leads Spain's medium-term cycles of both the balance of trade and the current account. The evidence for France and Germany is mixed. It is perhaps worth noting the results of the Germany-Spain pair where a medium-term cycle of embodied technical change and patents is positively correlated with and leads Spain's balance of trade.

The final piece of evidence on the international transmission of medium-term business cycles is gathered in Table 9 where we estimate pairwise cross-country correlations of technology variables and international relative prices. Noticeably, the medium-term cycles of embodied technical change, R&D expenditure, patent applications and the terms of trade of the U.K. and Italy correlate positively with and lead their respective counterpart in Spain. These cross-country coefficients are very large and highly significant. Similarly, the medium-term cycle of R&D and the terms of trade of Germany correlates positively with and leads Spain's respective medium-term cycle. For the case of France, there is a strong positive contemporaneous comovement of the patent applications and the terms of trade cycle. The medium-term cycle of the real effective exchange rate in Germany and the U.K. is positively correlated and leads Spain's counterpart. On the other hand, the medium-term cycle of TFP in France, Italy or the U.K. is negatively correlated with and leads Spain's TFP cycle.

Table 9

Pairwise cross-country correlations of other variables

	Spain (y(t)) with individual countries (y(t+k)) Medium-term cycle							
Other variables	**France**		**Germany**		**U.K.**		**Italy**	
Relative price of capital	0.49 (0.10,0.69)		-0.51 (-0.65,-0.36)	*	0.82 (0.71,0.90)	*	0.94 (0.87,0.97)	*
	k=5		k=-6		k=0		k=0	
TFP	-0.52 (-0.70,-0.27)	*	0.71 (0.50,0.84)		-0.49 (-0.68,-0.21)	*	-0.65 (-0.78,-0.36)	*
	k=-7		k=5		k=-6		k=-6	
R&D	-0.58 (-0.73,-0.34)	*	0.57 (0.28,0.77)	*	0.57 (-0.00,0.78)	*	0.71 (0.44,0.85)	*
	k=-10		k=-3		k=-2		k=-1	
Patents	0.80 (0.70,0.86)	*	-0.72 (-0.83,-0.56)	*	0.78 (0.72,0.83)	*	0.81 (0.72,0.86)	*
	k=0		k=-10		k=0		k=0	
Terms of trade	0.80 (0.60,0.88)	*	0.72 (0.54,0.86)	*	0.75 (0.56,0.85)	*	0.69 (0.54,0.81)	*
	k=0		k=0		k=-7		k=-4	
REER	-0.40 (-0.64,-0.13)		0.52 (0.31,0.67)	*	0.55 (0.36,0.69)	*	-0.45 (-0.64,-0.21)	
	k=6		k=-2		k=-7		k=2	

Source: Authors´ own calculations

A summary of the international medium-term business cycle features of the Europe-Spain pairs is provided next. First, the cross-country correlations between the macroeconomic aggregates of France, Germany, the U.K. and Italy with Spain's counterparts are largely positive, high and significant. The very large correlations of the France-Spain and the U.K.-Spain pairs, together with their relatively short lead structure, are remarkable characteristics. Second, the medium-term cycles of embodied technical change, patent applications and the terms of trade of France, Germany, the U.K. and Italy are positively correlated with, significant and lead Spain's macroeconomic aggregates, the exception being the negative correlation with Germany's cycle of embodied technical change. For the balance of trade and the current account, these cross-correlations are mostly negative. Third, the medium-term cycles of embodied technical change, R&D expenditure, patent applications and the terms of trade of the U.K. and Italy are positively correlated with and lead Spain's counterpart cycles, while this is only the case for Germany's R&D and the terms of trade cycles and France's patents and the terms of trade cycles.

For all the cross-country statistics considered in the paper, a remarkable feature of the medium-term cycle is the very large positive correlations and leads displayed by all the U.S. technology variables and the U.S. terms of trade over Spain's main macroeconomic aggregates. The corresponding evidence when the counterpart to Spain is a large European economy is weaker, particularly in the case of European technology cycles. This initial finding is somewhat surprising, and merits further attention in the future, as we might have expected stronger technology transmission linkages in the geographically closer and economically more integrated economies of Spain and her European neighbors.

Once the evidence from the unconditional correlations has been studied, the goal of the final section is to provide an initial assessment of whether the cross-country features of the medium-term cycle may have changed with Spain's process of international economic integration that took place during the postwar period.

6. Economic integration and international medium-term comovement

This section examines the impact of Spain's increased trade and financial linkages with the industrialized world on international medium-term business cycle comovement. In particular, we study the pattern of cross-country correlations before and after Spain's joining the EEC and test whether there has been a significant change in the extent of comovement. We have chosen 1986 as the break-date since it undoubtedly signifies a large institutional change for Spain's economic relationship with Europe.

In 1950, Spain's ratio of real imports to real GDP stood at 2.5 percent, the ratio increased to 7 percent over the 1960s and 1970s, it reached double-digits in 1986 and, since then, it continued on an upward trend towards a final figure well-above 30 percent of GDP in 2007. A similar pattern is recorded by the ratio of real exports to real GDP, possibly with two differences, a slightly earlier take-off in the 1980s and a flat export-to-GDP ratio for most of the first ten years of establishment of the EMU[26]. The bilateral trade pattern has also changed, e.g., in 1950, the share of Spain's total imports whose origin was the U.S., France and Germany stood, respectively, at 16.2, 9.7 and 5.0 percent while in 2007 the corresponding figures were 3.5, 12.3 and 15.3 percent. Previous studies on business cycle transmission have indicated that trade linkages are important determinants of business cycle comovement in the sense that countries that trade more with each other tend to exhibit more correlated business cycles (Baxter and Kouparitsas (2005)). Thus, we may find evidence suggesting that, as a result of Spain's joining the EEC, the extent of international comovement over the medium-term cycle increased in a statistically significant way.

Table 10 presents results of non-parametric Wilcoxon Rank Sum tests computed for the pairwise cross-country correlations of each of five macroeconomic aggregates, in particular, output, consumption, investment, the balance of trade and the current account, for various time lags, namely k={0, -1, -2}, and for two alternative groups, first, Spain vis-à-vis the four large European economies and, second, Spain vis-à-vis the four large European economies plus the U.S.

Table 10
Non-parametric equality tests of correlation coefficients between subperiods at different lags

		Spain vis-à-vis European countries		
		Median correlation coefficients		Difference of medians between subperiods
		1951-1985	1986-2007	
Output	k=0	0.68	0.65	-0.03 [0.89]
	k=-1	0.64	0.73	0.09 [0.56]
	k=-2	0.53	0.58	0.05 [0.67]
Consumption	k=0	0.79	0.50	-0.29 [0.06]
	k=-1	0.75	0.66	-0.09 [0.31]
	k=-2	0.65	0.54	-0.11 [0.47]
Investment	k=0	0.61	0.82	0.21 [0.47]
	k=-1	0.67	0.77	0.10 [1.00]
	k=-2	0.66	0.36	-0.30 [0.47]
Balance of trade/GDP	k=0	0.37	0.56	0.18 [0.88]
	k=-1	0.40	0.53	0.13 [0.66]
	k=-2	0.34	0.36	0.02 [0.88]
Current account/GDP	k=0	0.18	0.51	0.33 [0.31]
	k=-1	0.29	0.43	0.56 [0.56]
	k=-2	0.22	0.22	0.00 [1.00]

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26: Graphical evidence of Spain's trade patterns is provided in the Appendix.

Table 10 (cont.)

Non-parametric equality tests of correlation coefficients between subperiods at different lags

		Spain vis-à-vis European countries and U.S		
		Median correlation coefficients		Difference of medians between subperiods
		1951-1985	1986-2007	
Output	k=0	0.64	0.63	-0.01 [0.83]
	k=1	0.57	0.76	0.19 [0.25]
	k=2	0.61	0.64	0.03 [0.40]
Consumption	k=0	0.76	0.50	-0.26 [0.04]
	k=1	0.75	0.65	-0.10 [0.17]
	k=2	0.70	0.57	-0.13 [0.40]
Investment	k=0	0.37	0.72	0.35 [0.68]
	k=1	0.57	0.76	0.19 [0.92]
	k=2	0.63	0.40	-0.23 [0.68]
Balance of trade/GDP	k=0	0.24	0.59	0.35 [0.53]
	k=1	0.34	0.54	0.20 [0.30]
	k=2	0.47	0.37	-0.10 [0.83]
Current account/GDP	k=0	0.13	0.51	0.38 [0.14]
	k=1	0.22	0.50	0.28 [0.17]
	k=2	0.12	0.29	0.17 [0.61]

Note: p-values based on the Wilcoxon rank-sum test are reported in brackets.
Source: Authors´ own calculations

Overwhelmingly, the tests results cannot reject the null of the same continuous distribution across subperiods. We find an exception in the contemporaneous cross-country correlations of consumption, suggesting that international comovement may have declined after 1986, however this kind of evidence is neither found at any other lag nor shown by any other variable. Overall, these initial results do not lend support to the hypothesis that, over the medium-term cycle, a shift towards more economic integration is necessarily associated with increased international comovement[27].

27: Kose et al. (2003, 2008) and Artis et al. (2011), among others, reach a similar conclusion at high business-cycle frequencies.

7. Conclusions

Do medium-term oscillations whose origin is the technological leader transmit to follower countries? What are the main features of international medium-term business cycle comovement? Do we naturally observe, for example, stronger linkages in medium-term cycles when the leader and the follower countries are geographically closer or economically more integrated? To provide an answer to these questions this paper has extensively examined the evidence on the medium-term business cycle comovement between a catching-up economy, namely Spain, and each of the obvious candidate countries to technological leadership of the postwar period, i.e. the U.S., France, Germany, Italy and the U.K.

Our results suggest that Spain's medium-term cycle is very persistent and significantly more volatile than the conventional high-frequency cycle. The procyclicality of embodied and disembodied technical change, patent applications and the terms of trade characterizes the medium-term cycle in Spain. Regarding the international transmission of medium-term cycles, we show that the U.S. medium-term cycles of embodied and disembodied technical change, patent applications and the terms of trade are positively and strongly correlated with Spain's main macroeconomic aggregates. Furthermore, the U.S. technology and international relative price cycles display, on average, a three-year lead over Spain's output cycle. The corresponding evidence when the counterpart to Spain is a large European economy is weaker, particularly in the case of Europe's medium-term technology cycles. We consider the latter finding somewhat surprising since one might have expected stronger technology transmission linkages between economies that are closer, both geographically and economically. However, we also obtain initial results suggesting that Spain's institutional shift towards economic integration with Europe was not associated with increased international medium-term comovement. These findings merit further consideration in the future.

Overall, the evidence indicates that the international medium-term business cycle features described above are the result of the cross-country correlations at the medium-frequency and thus points out to the need of incorporating new mechanisms into medium-term business cycle models so that they are able to explain the strong lead displayed by the U.S. cycles of embodied and disembodied technical change, R&D expenditure, patent applications and the terms of trade over the output cycle of the recipient country.

Appendix

Data definitions and sources

The database contains information of 6 OECD countries and, for most of the variables, spans from 1950 until 2007. The countries in the sample include: France, Germany, Italy, Spain, United Kingdom and United States. Unless otherwise indicated, variables are expressed in U.S. $, constant prices, constant PPPs and OECD base year 2000.

GDP is the gross domestic product based on the expenditure approach taken from the OECD Economic Outlook, various volumes. For the period 1950-1959, the data are extrapolated using the International Financial Statistics of the IMF and the National Income Statistics of the United Nations.

Working-age population 15-64 is taken from the OECD Economic Outlook and the OECD Annual Labour Force Statistics, various volumes.

Hours is defined as the average hours worked per employee multiplied by the total number of employees. The data are from the OECD Economic Outlook (national accounts basis whenever available), various volumes, backdated with the OECD Annual Labour Force Statistics, B.R. Mitchell International Historical Statistics 1750-2005 Palgrave Macmillan, and the Total Economy Database of the Groningen Growth and Development Centre.

GDP deflator is an index taken from the OECD Economic Outlook, various volumes, with the exception of pre-1960 values that are from the AMECO database of the European Commission and the Yearbook of National Accounts Statistics of the United Nations, various issues.

Labor productivity is the ratio of GDP to total hours worked in the economy.

Consumption is the private final consumption expenditure of households and non-profit financial institutions serving households from the OECD Economic Outlook, various volumes. For the period 1950-1959, the data are extrapolated using the International Financial Statistics of the IMF and the National Income Statistics of the United Nations. Data for Spain starts in 1954.

Investment is the private non-residential gross fixed capital formation from the OECD Economic Outlook, various volumes. For the period 1950-1959, the data are extrapolated using the International Financial Statistics of the IMF and the National Income Statistics of the United Nations. Data for Spain starts in 1954.

Exports, Imports, Export and Import price deflators are from the OECD Economic Outlook, various volumes, the AMECO database of the European Commission, the International Financial Statistics of the IMF, the U.K. Office of National Statistics and the U.S. Bureau of Economic Analysis. Whenever necessary, the data for extrapolating the sample back to 1950 are taken from the OECD Statistics of National Accounts, various issues, the United Nations Historical Data 1900-1960, the United Nations Yearbook of International Trade Statistics, various issues, and Estadísticas Históricas de España, siglos XIX y XX, Fundación BBVA. The deflators are index numbers.

Balance of trade is defined as the ratio of net exports to GDP.

Terms of trade is an index defined as the ratio of the export price deflator to the import price deflator.

Bilateral exports are obtained by multiplying total exports by the corresponding bilateral exports shares. Bilateral exports shares are constructed from Feenstra et. al (2005) World Trade Flows: 1962-2000, NBER Working Paper No. 11040, giving primacy to trade flows reported by the importer country, and extended with the OECD International Trade by Commodity Statistics, B.R. Mitchell International Historical Statistics 1750-2005 Palgrave Macmillan, the United Nations Yearbook of International Trade Statistics, various issues, and Estadísticas Históricas de España, siglos XIX y XX, Fundación BBVA. A similar method and data sources are used for the construction of the Bilateral imports series.

Bilateral real exchange rate is an index defined as the ratio of the GDP deflator of the first country to the GDP deflator of the second country adjusted by the corresponding nominal exchange rate. Data on nominal exchange rates are from the International Financial Statistics of the IMF.

Real effective exchange rate is an index constructed as the trade-weighted average of bilateral real exchange rates. Trade-weights are based on export shares.

Current account is defined as the ratio of the current account balance to GDP, both in nominal terms. The current account balance is taken from the Balance of Payments of OECD countries, various issues, the Balance of Payments Database of the IMF, Banque de France, Banca d'Italia, U.K. Office of National Statistics, and Estadísticas Históricas de España, siglos XIX y XX, Fundación BBVA. Nominal GDP is from the International Financial Statistics of the IMF.

Total factor productivity is calculated as the residual of a standard Cobb-Douglas production function on capital stock and labour use. The estimated capital stock series are based on investment series from the OECD Economic Outlook and the OECD Statistics of National Accounts, various issues.

Quality-adjusted relative price of capital is an index defined as the ratio of the quality-adjusted price of total assets (excluding residential investment) and the price of consumption goods. Both price series are available in the EU-KLEMS database of the Groningen Growth and Development Centre for Germany, Italy, Spain and the U.K. in the period 1970-2007. The EU-KLEMS database does not provide the series of the price of capital for France. In the latter case, we have used the Törnquivst index to construct the quality-adjusted price of capital based on data of gross fixed capital formation from INSEE for the period 1970-2007 and on the methodology in R.J. Gordon (1990) The Measurement of Durable Goods, University of Chicago Press. U.S. data span from 1950 until 2007 and are taken from Gordon (1990) for the period 1950-1983 and extrapolated till the end of the sample following the method described in J. Cummins and G. Violante (2002) "Investment-Specific Technical Change in the Unites States (1947-2000): Measurement and Macroeconomic Consequences" *Review of Economic Dynamics,* Vol. 5, pp. 243-284.

Price mark-up is an index defined as the ratio of the unit labor costs and the GDP deflator. Series of unit labor costs are taken from the International Labor Comparison elaborated by the U.S. Bureau of Labor Statistics. The GDP deflator is taken from the data sources specified above. For Spain, the data start in 1979, we extrapolate the sample back to 1955 by using unit labor costs data from Ministerio de Economía y Hacienda.

R&D spending is the Business Enterprise Research and Development Expenditure from the OECD ANBERD Database. The data start in 1973 with the exception of the U.K., that start in 1966 and data are from the Office of National Statistics, and the U.S., that start in 1953 and data are from the National Science Foundation.

Patent applications are taken from the World Intellectual Property Organization Statistics Database and the European Patent Office Annual Report, Statistical Tables, various issues.

The cross-country correlations with Europe

Table A.1.

Cross-country correlations of other variables (Europe) with macroeconomic aggregates (Spain)

	Spain (y(t)) with individual countries (y(t+k)); Medium-term cycle Hours (Spain)							
Other variables	**France**		**Germany**		**U.K.**		**Italy**	
Relative price of capital	-0.72 (-0.83,-0.58)	*	0.48 (0.34,0.60)	*	-0.81 (-0.89,-0.66)	*	-0.76 (-0.88,-0.59)	*
	k=-4		k=-2		k=-1		k=-1	
TFP	-0.67 (-0.76,-0.56)	*	-0.57 (-0.72,-0.34)		-0.67 (-0.77,-0.51)	*	-0.42 (-0.61,-0.21)	*
	k=-10		k=9		k=-10		k=-10	
R&D	-0.80 (-0.90,-0.60)		0.85 (0.62,0.93)		0.57 (0.32,0.74)		0.70 (0.48,0.83)	
	k=5		k=10		k=10		k=10	
Patents	0.62 (0.37,0.77)	*	0.50 (0.27,0.69)		0.65 (0.49,0.76)	*	0.56 (0.37,0.70)	*
	k=-6		k=9		k=-2		k=-3	
Terms of trade	0.73 (0.56,0.84)	*	0.65 (0.41,0.78)	*	0.65 (0.50,0.77)	*	0.62 (0.43,0.75)	*
	k=-3		k=-3		k=-8		k=-8	
Bilateral exports	0.61 (0.42,0.75)	*	0.64 (0.47,0.77)	*	0.69 (0.52,0.80)	*	0.63 (0.42,0.75)	*
	k=-3		k=-3		k=-5		k=-3	
Bilateral imports	-0.46 (-0.63,-0.25)	*	-0.66 (-0.77,-0.49)		0.42 (0.16,0.61)	*	-0.45 (-0.59,-0.31)	
	k=-10		k=-10		k=-3		k=-10	
Bilateral real exchange rate	0.51 (0.30,0.66)	*	0.58 (0.38,0.73)	*	0.57 (0.41,0.71)	*	0.64 (0.45,0.77)	*
	k=-10		k=-5		k=-8		k=-7	

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Table A1.

Cross-country correlations of other variables (Europe) with macroeconomic aggregates (Spain)

	Consumption (Spain)							
Other variables	**France**		**Germany**		**U.K.**		**Italy**	
Relative price of capital	-0.53 (-0.67,-0.33)	*	-0.35 (-0.52,-0.14)		-0.78 (-0.88,-0.61)	*	-0.85 (-0.92,-0.73)	*
	k=-4		k=5		k=-2		k=-1	
TFP	-0.70 (-0.79,-0.60	*	-0.60 (-0.76,-0.34)		-0.73 (-0.81,-0.56)	*	0.53 (0.21,0.74)	*
	k=10		k=9		k=10		k=-2	
R&D	-0.73 (-0.84,-0.57)		0.83 (0.60,0.92)		0.54 (0.25,0.73)		-0.69 (-0.83,-0.46)	
	k=5		k=10		k=10		k=2	
Patents	0.76 (0.58,0.86)	*	0.46 (0.24,0.65)	*	0.67 (0.48,0.81)	*	0.70 (0.48,0.85)	*
	k=-8		k=-3		k=-5		k=-8	
Terms of trade	0.76 (0.60,0.85)	*	0.66 (0.46,0.81)	*	0.76 (0.58,0.85)	*	-0.74 (-0.85,-0.51)	
	k=-4		k=-3		k=-9		k=7	
Bilateral exports	0.72 (0.59,0.81)	*	0.75 (0.61,0.84)	*	0.72 (0.59,0.81)	*	0.75 (0.64,0.84)	*
	k=-3		k=-3		k=-4		k=-3	
Bilateral imports	-0.57 (-0.70,-0.36)	*	-0.62 (-0.76,-0.43)		-0.51 (-0.69,-0.28)		-0.55 (-0.70,-0.37)	
	k=10		k=10		k=3		k=9	
Bilateral real exchange rate	0.56 (0.37,0.70)	*	-0.55 (-0.73,-0.33)		0.69 (0.53,0.80)	*	0.68 (0.52,0.78)	*
	k=10		k=10		k=10		k=-8	
	Investment (Spain)							
Other variables	**France**		**Germany**		**U.K.**		**Italy**	
Relative price of capital	-0.49 (-0.69,-0.13)		0.35 (0.17,0.45)	*	-0.75 (-0.86,-0.55)	*	-0.83 (-0.91,-0.70)	*
	k=4		k=-1		k=-1		k=0	
TFP	-0.83 (-0.90,-0.73)	*	-0.49 (-0.70,-0.22)		-0.79 (-0.87,-0.64)	*	-0.56 (-0.70,-0.37)	*
	k=10		k=10		k=10		k=-9	
R&D	-0.73 (-0.84,-0.57)		0.56 (0.30,0.78)		-0.57 (-0.75,-0.23)		-0.74 (-0.88,-0.52)	
	k=5		k=10		k=3		k=4	
Patents	0.75 (0.63,0.83)	*	-0.51 (-0.68,-0.30)	*	0.66 (0.50,0.77)	*	0.66 (0.53,0.77)	*
	k=-3		k=-10		k=-2		k=-3	
Terms of trade	0.78 (0.65,0.86)	*	0.61 (0.38,0.77)	*	0.75 (0.58,0.86)	*	0.72 (0.51,0.87)	*
	k=-2		k=-2		k=-7		k=-3	
Bilateral exports	0.80 (0.68,0.87)	*	0.83 (0.70,0.91)	*	0.82 (0.69,0.89)	*	0.84 (0.71,0.90)	*
	k=-2		k=-2		k=-3		k=-2	
Bilateral imports	-0.62 (-0.75,-0.44)	*	-0.54 (-0.69,-0.33)		0.48 (0.24,0.64)	*	-0.58 (-0.72,-0.36)	
	k=-9		k=10		k=-3		k=10	
Bilateral real exchange rate	0.59 (0.41,0.72)	*	0.54 (0.29,0.71)	*	0.77 (0.63,0.86)	*	0.78 (0.61,0.87)	*
	k=10		k=-5		k=-8		k=-6	

Source: Authors´ own calculations

Table A.2.

Cross-country correlations of other variables (Europe) with macroeconomic aggregates (Spain)

	Spain (y(t)) with individual countries (y(t+k)); Medium-term cycle							
	Exports (Spain)							
Other variables	**France**		**Germany**		**U.K.**		**Italy**	
Relative price of capital	-0.73 (-0.86,-0.49)	*	-0.65 (-0.79,-0.36)		-0.65 (-0.81,-0.40)	*	-0.80 (-0.90,-0.61)	*
	k=-2		k=10		k=-5		k=-6	
TFP	0.58 (0.34,0.77)		-0.44 (-0.58,-0.27)		0.43 (0.16,0.66)		0.75 (0.63,0.84)	
	k=1		k=5		k=1		k=1	
R&D	-0.75 (-0.89,-0.48)		-0.83 (-0.92,-0.63)	*	-0.59 (-0.77,-0.30	*	-0.87 (-0.93,-0.73)	*
	k=1		k=-4		k=-2		k=-1	
Patents	0.56 (0.41,0.67)	*	0.28 (-0.04,0.54)	*	0.41 (0.25,0.56)	*	0.49 (0.34,0.61)	*
	k=-10		k=-10		k=-10		k=-10	
Terms of trade	0.45 (0.25,0.59)	*	-0.58 (-0.71,-0.40)		-0.61 (-0.75,-0.41)		-0.60 (-0.73,-0.41)	
	k=-10		k=6		k=4		k=5	
Bilateral exports	0.79 (0.64,0.88)	*	0.71 (0.53,0.83)	*	0.71 (0.52,0.82)	*	0.68 (0.48,0.80)	*
	k=-8		k=-7		k=-8		k=-8	
Bilateral imports	0.59 (0.43,0.73)		-0.47 (-0.61,-0.22)		0.45 (0.26,0.61)	*	-0.62 (-0.75,-0.48)	
	k=2		k=5		k=-10		k=5	
Bilateral real exchange rate	-0.42 (-0.63,-0.13)		-0.58 (-0.69,-0.47)		-0.41 (-0.64,-0.15)		-0.58 (-0.72,-0.37)	
	k=4		k=6		k=4		k=4	
	Imports (Spain)							
Other variables	**France**		**Germany**		**U.K.**		**Italy**	
Relative price of capital	-0.67 (-0.81,-0.40)		0.39 (0.27,0.55)	*	-0.74 (-0.85,-0.55)	*	-0.81 (-0.91,-0.62)	*
	k=4		k=0		k=0		k=-1	
TFP	-0.78 (-0.86,-0.66)	*	-0.49 (-0.64,-0.22)		-0.69 (-0.80,-0.51)	*	-0.59 (-0.74,-0.37)	
	k=-10		k=9		k=-9		k=-10	*
R&D	-0.90 (-0.95,-0.80)		0.56 (0.23,0.77)		-0.67 (-0.84,-0.37)		-0.88 (-0.94,-0.74)	
	k=6		k=10		k=3		k=4	
Patents	0.68 (0.54,0.77)	*	0.49 (0.24,0.70)	*	0.57 (0.42,0.69)	*	0.57 (0.39,0.69)	*
	k=-3		k=-1		k=-2		k=-3	
Terms of trade	0.83 (0.73,0.89)	*	0.67 (0.50,0.79)	*	0.71 (0.52,0.82)	*	0.75 (0.61,0.85)	*
	k=-3		k=-2		k=-7		k=-3	
Bilateral exports	0.87 (0.81,0.91)	*	0.81 (0.72,0.88)	*	0.83 (0.69,0.90)	*	0.88 (0.81,0.93)	*
	k=0		k=0		k=-2		k=-1	
Bilateral imports	-0.68 (-0.79,-0.49)	*	-0.44 (-0.65,-0.13)		0.41 (0.24,0.58)	*	0.59 (0.39,0.71)	*
	k=-8		k=10		k=-3		k=-3	
Bilateral real exchange rate	0.59 (0.43,0.74)	*	0.62 (0.45,0.75)	*	0.69 (0.53,0.79)	*	0.76 (0.64,0.85)	*
	k=-10		k=-4		k=-9		k=-6	

Source: Authors´ own calculations

Table A.3.

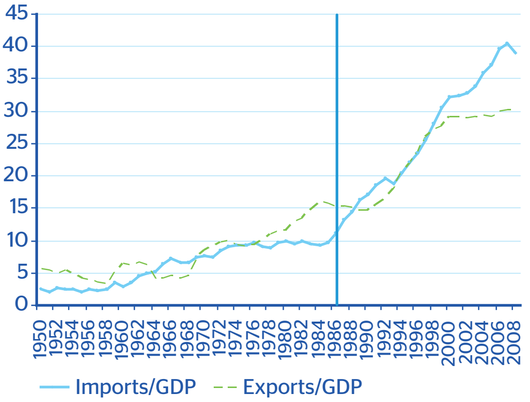
Cross-country correlations of other variables (Europe) with macroeconomic aggregates (Spain)

	Spain (y(t)) with individual countries (y(t+k)); Medium-term cycle							
	Balance of trade (Spain)							
Other variables	**France**		**Germany**		**U.K.**		**Italy**	
Relative price of capital	0.67 (0.39,0.83)		-0.65 (-0.85,-0.27)	*	0.71 (0.48,0.86)	*	0.71 (0.51,0.83)	*
	k=5		k=-5		k=0		k=0	
TFP	0.62 (0.46,0.74)	*	0.34 (0.13,0.51)		-0.53 (-0.67,-0.36)		0.41 (0.16,0.60)	*
	k=-10		k=9		k=8		k=-9	
R&D	0.82 (0.57,0.91)		0.74 (0.45,0.87)		0.67 (0.40,0.84)		0.80 (0.64,0.90)	
	k=7		k=4		k=4		k=5	
Patents	-0.70 (-0.77,-0.59)	*	0.50 (0.29,0.67)	*	-0.65 (-0.75,-0.51)	*	-0.67 (-0.75,-0.54)	*
	k=-2		k=-10		k=-3		k=-3	
Terms of trade	-0.65 (-0.77,-0.48)	*	-0.49 (-0.68,-0.28)	*	-0.57 (-0.74,-0.35)	*	-0.58 (-0.74,-0.38)	*
	k=-2		k=-3		k=-8		k=-3	
Bilateral exports	-0.59 (-0.73,-0.41)	*	-0.66 (-0.79,-0.45)	*	-0.62 (-0.76,-0.41)	*	-0.63 (-0.80,-0.43)	*
	k=-2		k=-2		k=-2		k=-1	
Bilateral imports	0.48 (0.17,0.70)	*	-0.48 (-0.65,-0.22)	*	-0.66 (-0.76,-0.49)	*	0.48 (0.31,0.62)	
	k=-8		k=-9		k=-3		k=10	
Bilateral real exchange rate	-0.58 (-0.70,-0.37)	*	-0.61 (-0.72,-0.47)	*	-0.73 (-0.80,-0.63)	*	-0.72 (-0.86,-0.57)	*
	k=-5		k=-5		k=-6		k=-5	
	Current account (Spain)							
Other variables	**France**		**Germany**		**U.K.**		**Italy**	
Relative price of capital	0.53 (0.29,0.66)	*	-0.62 (-0.82,-0.12)	*	0.69 (0.33,0.83)	*	0.57 (0.34,0.73)	*
	k=-4		k=-5		k=-2		k=-2	
TFP	0.25 (0.03,0.42)	*	0.29 (0.00,0.51)		-0.30 (-0.51,-0.04)	*	-0.35 (-0.56,-0.08)	*
	k=-10		k=1		k=-3		k=-4	
R&D	0.52 (0.25,0.73)		-0.65 (-0.86,-0.27)		0.42 (0.15,0.66)	*	-0.50 (-0.72,-0.13)	
	k=5		k=10		k=-8		k=10	
Patents	-0.34 (-0.49,-0.13)	*	-0.26 (-0.45,-0.01)	*	-0.36 (-0.56,-0.08)	*	-0.37 (-0.54,-0.13)	*
	k=-2		k=-2		k=-3		k=-3	
Terms of trade	-0.40 (-0.58,-0.19)	*	-0.40 (-0.60,-0.19)	*	-0.41 (-0.62,-0.15)	*	-0.28 (-0.47,-0.05)	*
	k=-3		k=-4		k=-9		k=-10	
Bilateral exports	-0.37 (-0.59,-0.18)	*	-0.37 (-0.55,-0.15)	*	-0.32 (-0.50,-0.12)	*	-0.30 (-0.50,-0.08)	*
	k=-3		k=-3		k=-3		k=-2	
Bilateral imports	-0.38 (-0.59,-0.20)	*	-0.39 (-0.57,-0.11)	*	-0.53 (-0.69,-0.30)	*	0.44 (0.29,0.62)	
	k=-3		k=-10		k=-3		k=1	
Bilateral real exchange rate	0.32 (0.08,0.58)		-0.43 (-0.58,-0.27)	*	-0.34 (-0.56,-0.13)	*	0.33 (0.04,0.56)	
	k=1		k=-5		k=-7		k=1	

Source: Authors´ own calculations

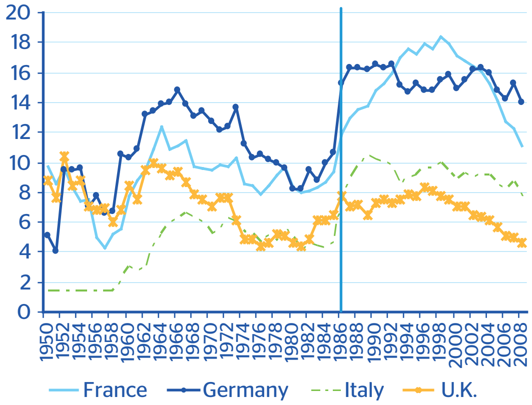
The pattern of exports and imports in Spain

Figure A.1.
Spain:
Ratio of imports and exports to GDP, volume (%)



Source: Authors´ own calculations

Figure A.2.
Spain:
Share of bilateral imports in total imports (%)



Source: Authors´ own calculations

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