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International Business Cycles

Theory and Evidence

Have the conclusions changed?

Reassessing Backus, Kehoe and Kydland (1993)

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Abstract

Backus, Kehoe and Kydland (1993) documented several empirical regularities in international business cycles. In particular, output is more highly correlated across countries than consumption, whereas their models predict the opposite ranking. This discrepancy is known as the quantity anomaly. Given the influence of these findings on subsequent research, we reassess their results using 23 additional years of data. Although cross-country correlations have generally decreased, we find that the quantity anomaly persists.

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About this edition. This Typst edition was prepared in September 2026 from the thesis source, initially at `9bef204`, with subsequent prose revisions synchronized from LaTeX. The thesis's 2015 argument and conclusions are retained; the 2026 research extension is a separate work. Tables 4–7 retain the values and historical comparisons printed in the submitted PDF. Charts are redrawn from the archived thesis data. Layout, citation style, table orientation and figure styling have been modernized.

Contents

Abbreviations

Code	Meaning
AUS	Australia
AUT	Austria
CAN	Canada
CHE	Switzerland
DEU	Germany
EU15	European aggregate
FRA	France
GBR	United Kingdom
ITA	Italy
JPN	Japan
USA	United States
ACZ	Ambler et al. (2004)
BKK / BKK (1993)	Backus et al. (1993)
BKK (1992)	Backus et al. (1992)
OECD	Organisation for Economic Co-operation and Development
RBC	Real Business Cycle

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1 Introduction

As Rebelo (2005) explains, Finn Kydland and Edward Prescott's 1982 paper, "Time to Build and Aggregate Fluctuations", introduced three major ideas into macroeconomics. First, dynamic general equilibrium models provide a useful framework for studying business cycles. Second, business cycle models can be consistent with the empirical regularities of long-run growth. Third, calibrating models with micro-economic data and the economy's long-run properties allows researchers to compare simulated and observed data quantitatively.

David Backus, Patrick Kehoe and Finn Kydland applied these ideas in "International Business Cycles: Theory and Evidence" (1993),[1] hereafter BKK or BKK (1993). They extended Kydland and Prescott (1982)'s real business cycle (RBC) model to include a second country, calibrated and simulated the model, and compared its predictions with empirical regularities observed in the second half of the twentieth century. One discrepancy stood out for its robustness: cross-country output correlations were higher in the data than in the model, while consumption correlations were lower. Because this discrepancy persisted across calibrations and substantial changes to the model's structure, it became known as the quantity anomaly. These empirical findings shaped subsequent research, and many later dynamic stochastic general equilibrium (DSGE) models sought to account for them.

This paper reassesses BKK's influential empirical findings using 23 additional years of data. Section 2 introduces BKK's baseline model and compares it with its closed-economy counterpart. It also describes modifications that resolve some discrepancies between the model and the data but leave the quantity anomaly unresolved. Section 3 describes our data, explains how they compare with BKK's, and discusses the implications of using the Hodrick-Prescott filter. In Section 4, we repeat BKK's calculations over a longer sample period. We then examine all country pairs rather than only those involving the United States, comparing our results with both BKK's and those of Ambler et al. (2004). We find that the quantity anomaly persists and conclude by discussing how subsequent research has sought to explain it.

This paper also aims to make its analysis reproducible.[2] The data and the R code used in the original analysis are available online, together with instructions for reproducing the results.[3]

[1] The paper was later published in *Frontiers of Business Cycle Research*, edited by Thomas F. Cooley ((1995)).

[2] Replication is a central standard for assessing scientific research, but independently repeating every stage of an empirical study is not always feasible. Reproducible research provides an intermediate standard: publishing the data and code allows others to verify how the reported results were obtained. See Peng (n.d.).

[3] The code, instructions and data are available at https://github.com/denismaciel/academia/tree/main/theses/bachelor-business-cycles.

2 The Model

Dynamic general equilibrium models can explain many features of business cycles (Prescott (1986)). In Kydland and Prescott (1982)‘s closed-economy model, fluctuations arise from a single aggregate productivity shock. The model accounts for the magnitude of fluctuations in output, consumption and investment, as well as the correlations of consumption and investment with output. It reproduces two central empirical regularities: consumption and investment are procyclical, and investment is more volatile than output while consumption is less volatile.

2.1 BKK’s Expanded Model

Backus et al. (1992) extend this framework to two countries with imperfectly correlated technology shocks. Their aim is to explain international business cycles within the RBC framework. The model must explain fluctuations within each country as well as comovements between countries.

BKK (1993) use a simpler version of the two-country model developed in BKK (1992). The countries produce a single good and share the same preferences and production technology. Country-specific shocks to total factor productivity are the sole source of uncertainty and drive business cycle fluctuations. Households maximize lifetime utility, which depends on consumption and leisure, and supply labor. Firms combine labor and capital to produce output.

Table 1 reports simulations from four models. The first row presents Kydland and Prescott (1982)‘s closed-economy model. The second presents BKK’s (1993) baseline two-country model, with complete markets and no transport costs. The remaining rows introduce transport costs and eliminate trade between the countries, respectively.

Access to international borrowing changes the behavior of consumption and investment because expenditure is no longer constrained by domestic production. Both variables become less correlated with output than in the closed-economy model. Investment also becomes more volatile: when resources can move freely across borders, the country experiencing the more favorable technology shock attracts more capital than it would in a closed economy.

(a) Volatility: standard deviations and ratios to output

Model	σ_y	σ_{nx}	c	x	n	z
Closed economy	1.80	—	0.35	3.58	0.58	0.50
Benchmark	1.50	3.77	0.42	10.99	0.50	0.67
Transport cost	1.35	0.37	0.47	2.91	0.47	0.75
Autarky	1.26	—	0.54	2.65	0.91	0.99

(b) Within-country correlations with output

Model	c	x	nx	n	z
Closed economy	.94	.80	—	.93	.90
Benchmark	.77	.27	.01	.93	.89
Transport cost	.81	.92	.23	.92	.98
Autarky	.90	.96	—	.91	.99

(c) Cross-country correlations

Model	y	c	x	n	z
Benchmark	−.21	.88	−.94	−.78	.25
Transport cost	−.05	.89	−.48	−.70	.25
Autarky	.08	.56	−.31	−.51	.25

Table 1: Standard Deviations, Within- and Cross-country Comovements from Models

2.2 The Quantity Anomaly

The simplest two-country RBC model, with free movement of goods and financial assets and no transport costs, differs from the data in several respects (Table 1: Benchmark). Investment and net exports are too volatile, consumption is too smooth, and output is negatively correlated across the two countries. The closed-economy model therefore reproduces these empirical features more successfully than its international counterpart. Changes to the model's parameters or structure reduce most of these discrepancies. For example, the model's net export and investment volatilities are initially seven and three times their empirical counterparts, respectively. Introducing quadratic transport costs brings them closer to the observed levels (Table 1: Transport Cost).

One discrepancy, however, is particularly robust. The model predicts that consumption is more highly correlated across countries than output, $\rho_{c,c^*} > \rho_{y,y^*}$, whereas the data show the opposite ranking, $\rho_{y,y^*} > \rho_{c,c^*}$. BKK call this discrepancy the quantity anomaly[4] because it persists across changes to both the model's parameters and its structure.

2.3 Robustness of the Quantity Anomaly

The baseline model produces a cross-country output correlation of −0.21. In BKK's data, by contrast, output correlations between the United States and the other ten countries are all positive, ranging from 0.38 for Austria to 0.76 for Canada. The model generates a negative correlation because a favorable technology shock raises the marginal productivity of labor and capital in the affected country. Higher returns attract productive resources from the other country, so output rises in one country at the expense of the other.

Consumption is perfectly correlated across countries when markets are complete, allowing international risk sharing, and preferences are additively separable between consumption and leisure (Scheinkman

[4]BKK (1993) also identify a second anomaly: the standard deviation of the terms of trade is larger in the data than in the model. This paper focuses on the quantity anomaly.

(1984)). BKK's benchmark model has complete markets but nonseparable preferences, so its consumption correlation is 0.88 rather than one. This is still much higher than the empirical correlation between the United States and Europe, which is 0.51.

To address the high consumption correlation and low output correlation, BKK eliminate international risk sharing altogether (Table 1: Autarky). Neither goods nor securities can be traded, leaving correlated technology shocks as the only link between the countries. Consumption correlation falls to 0.56, but output correlation remains low at 0.08, compared with 0.70 between the United States and Europe in the data. BKK suggest that the persistent consumption correlation under autarky may reflect the permanent income hypothesis. When a favorable technology shock occurs in one country, households in the other anticipate that its effects will spill over. They therefore increase current consumption and postpone investment.

Output and consumption correlations are closely linked in the model. Making productivity shocks more highly correlated raises cross-country output correlation but lowers consumption correlation. Different shock correlations can therefore reproduce either the observed output correlation or the observed consumption correlation, but not both simultaneously. The anomaly therefore concerns the ranking of output and consumption correlations, rather than either measure alone.

3 The Data

3.1 BKK's Two Papers

Backus, Kehoe and Kydland examine international business cycles in two papers: "International Real Business Cycles" (1992) and "International Business Cycles: Theory and Evidence" (1993). Both report output and consumption correlations between the United States and other countries, but their data sources, country samples and observation periods differ. These choices lead to meaningful differences in their results.

BKK (1993) use the same sample period for every country and variable: 1970:1 to 1990:2. Their data come from the OECD's *Quarterly National Accounts* and *Main Economic Indicators*.[5] They examine 11 countries, two fewer than BKK (1992); both samples include a European aggregate. BKK (1992) use the IMF's *International Financial Statistics*, with sample periods that vary by country. The longest series covers the United States from 1960:1 to 1990:2, while the shortest covers the European aggregate from 1970:1 to 1986:4.

The differences in sources and sample periods matter. The Australia–US output correlation differs by 0.26 between the papers. The France–US consumption correlation differs by 0.40, rising from −0.18 in BKK (1992) to 0.22 in BKK (1993). To make our reassessment of BKK (1993) comparable, we therefore use sources and measures as close as possible to theirs.

Despite these differences, the papers share several central findings. Output correlations are positive for all countries except South Africa in BKK (1992), and consumption is much less highly correlated across countries than the model predicts. Some consumption correlations with the United States are even negative: Australia in BKK (1993), and Finland, France and South Africa in BKK (1992).

Throughout the remainder of this paper, BKK refers to "International Business Cycles: Theory and Evidence" (1993).

3.2 Our Data

Our sample contains the same countries as BKK's: Australia (AUS), Austria (AUT), Canada (CAN), France (FRA), Germany (DEU), Italy (ITA), Japan (JPN), Switzerland (CHE), the United Kingdom (GBR), the United States (USA), and a European aggregate (EU15).[6]

We also draw on the OECD's *Quarterly National Accounts* and *Main Economic Indicators*. BKK provide limited information about their measurement choices, stating only that output, consumption, fixed investment and government purchases are measured in real terms, while the net exports-to-output ratio is calculated at current prices. Of the 20 potentially relevant OECD measures, we select VPVOBARSA[7] for output, consumption, investment and government spending. We use CPCARSA,[8] its current-price counterpart, to calculate the net exports-to-output ratio. Appendix Appendix A.1 explains these choices.

Following BKK, we calculate Solow residuals from $\log z = \log y - [\theta \log k + (1-\theta)\log n]$, omitting the capital term $\theta \log k$.

We construct the civilian employment series by combining the OECD's *Short-Term Labour Market Statistics* and *Main Economic Indicators*, as described in Appendix Appendix A.2. Table 2 summarizes the variables and their OECD codes and measures.

[5] BKK (1993) also use the IMF's *International Financial Statistics* for exchange-rate data, which are outside the scope of this paper.

[6] Our European aggregate comprises fifteen countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom. BKK do not specify the composition of their European aggregate.

[7] VPVOBARSA denotes seasonally adjusted volume estimates at constant 2010 prices, converted using 2010 purchasing power parities and expressed in US dollars at annual levels.

[8] CPCARSA denotes seasonally adjusted values at current prices and current purchasing power parities, expressed in US dollars at annual levels.

Variable	Name	Code	Measure
y	Gross domestic product — expenditure approach	B1_GE	VPVOBARSA
c	Private final consumption expenditure	P31S14_S15	VPVOBARSA
x	Gross fixed capital formation	P51	VPVOBARSA
g	General government final consumption expenditure	P3S13	VPVOBARSA
n	Employed population, aged 15 and over, all persons	LFEMTTTT	STSA
nx	Exports of goods and services	P6	CPCARSA
	Imports of goods and services	P7	CPCARSA
	Gross domestic product — expenditure approach	B1_GE	CPCARSA

Table 2: Variable Specification of OECD

We extend BKK's sample both forward, adding 23 years of more recent data, and backward, including earlier observations available in the OECD database. Table 3 reports the coverage of each variable and country. Most series run from 1960:1 to 2015:1, although some US and UK series begin in 1947:1 and 1955:1, respectively. Backus and Kehoe (1992) provide estimates for longer periods, including years before the Second World War. These earlier estimates are less reliable than the post-1945 data and are not considered here.

Country	GDP	Consumption	Investment	Government	Net exports	Employment
AUS	1960:1 – 2015:1	1960:1 – 2015:1	1960:1 – 2015:1	1960:1 – 2015:1	1960:1 – 2015:1	1967:1 – 2015:2
AUT	1960:1 – 2015:2	1960:1 – 2015:2	1960:1 – 2015:2	1960:1 – 2015:2	1960:1 – 2015:1	1969:1 – 2015:1
CAN	1960:1 – 2015:1	1960:1 – 2015:1	1960:1 – 2015:1	1960:1 – 2015:1	1960:1 – 2015:1	1955:1 – 2015:2
CHE	1960:1 – 2015:1	1960:1 – 2015:1	1960:1 – 2015:1	1960:1 – 2015:1	1960:1 – 2015:1	—
DEU	1960:1 – 2015:2	1960:1 – 2015:1	1960:1 – 2015:1	1960:1 – 2015:1	1960:1 – 2015:1	1962:1 – 2015:1
EU15	1961:1 – 2015:1	1961:1 – 2014:4	1961:1 – 2014:4	1961:1 – 2014:4	1960:1 – 2015:1	—
FRA	1960:1 – 2015:2	1960:1 – 2015:2	1960:1 – 2015:2	1960:1 – 2015:2	1960:1 – 2015:1	1978:1 – 2013:4
GBR	1955:1 – 2015:2	1955:1 – 2015:1	1955:1 – 2015:1	1955:1 – 2015:1	1960:1 – 2015:1	1969:2 – 2015:1
ITA	1960:1 – 2015:2	1960:1 – 2015:1	1960:1 – 2015:1	1960:1 – 2015:1	1960:1 – 2015:1	1959:1 – 2015:1
JPN	1960:1 – 2015:2	1960:1 – 2015:2	1960:1 – 2015:2	1960:1 – 2015:2	1960:1 – 2015:1	1955:1 – 2015:2
USA	1947:1 – 2015:2	1947:1 – 2015:2	1955:1 – 2015:2	1955:1 – 2015:2	1947:1 – 2015:2	1955:1 – 2015:2

Each cell gives first–last quarter. A dash denotes an unavailable series.

Table 3: Length of the Time Series for each Country

3.3 Hodrick-Prescott Filter

Analyzing international comovements requires a definition of the business cycle. Economic time series can be decomposed into a slowly varying growth trend and a more rapidly changing cyclical component. Neither component is directly observable in the recorded series. The researcher must therefore choose a method for estimating the trend and identifying deviations from it.

For comparability with BKK, we use the Hodrick-Prescott (HP) filter described in Hodrick and Prescott (1981). The filter emphasizes medium- and high-frequency movements and "can be thought of as removing a smooth trend line (like one might draw freehand) from the data" (Backus and Kehoe (1992)).

According to Baxter (1995), the resulting cyclical component is stationary if the input series is integrated of order four or less. Figure 1 illustrates the decomposition of US GDP into trend and cycle.

The parameter λ penalizes variation in the trend: a larger value produces a smoother trend. Following Hodrick and Prescott (1981), we set $\lambda = 1,600$ for quarterly data.

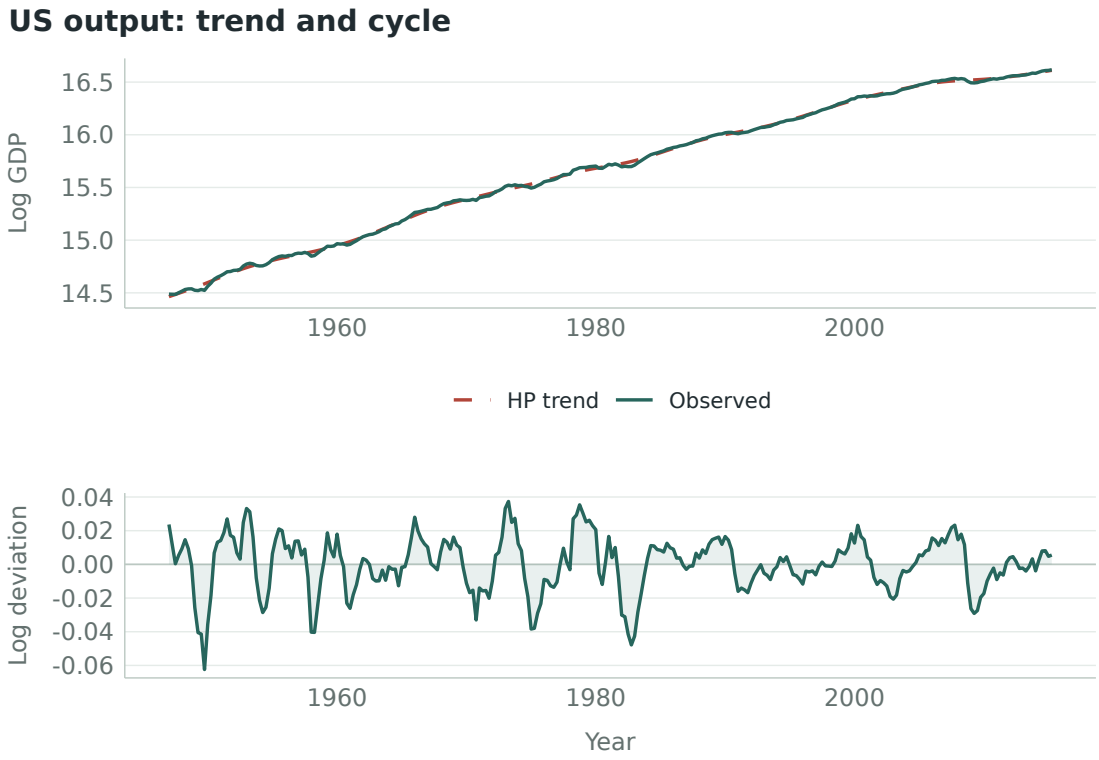


Figure 1: GDP of the United States detrended with Hodrick-Prescott Filter

Despite its widespread use, the HP filter has been criticized for its effects on measured business cycle properties. King and Rebelo (1993) find that it reduces standard deviations and substantially alters correlations between variables. They also argue that the conditions under which it minimizes the mean squared error are unlikely to hold in practice. Mechanical application can therefore remove variation normally associated with business cycles. Conversely, Cogley and Nason (1995) show that applying the filter to integrated time series can create apparent business cycle patterns that are absent from the underlying data. More recently, Phillips and Jin (2015) find that HP detrending generally fails to remove stochastic trends, contrary to a common assumption in applied macroeconomics.

The HP filter may also perform poorly during prolonged recessions.[9] During a deep slump, the estimated trend can flatten, reducing the measured deviation of output from trend. This can understate the depth or duration of a downturn and is a concern when interpreting the Great Recession. In our filtered US series, output remains below trend from 2008:4 to 2011:4. The National Bureau of Economic Research dates the end of the recession to June 2009, Thus, being below the estimated trend should not be equated with being in an officially dated recession.

[9] A discussion of this issue in the economic blogosphere is summarized at https://bruegel.org/2012/07/blogs-review-hp-filters-and-business-cycles/.

4 The Results

We assess whether the empirical regularities identified by BKK in 1993 persist in our longer sample, with particular attention to international comovements. Where relevant, we report BKK's estimates alongside ours in the discussion.

4.1 Within-Country Comovements and Volatility

Table 4 and Table 5 report standard deviations and within-country correlations, respectively. In Table 4, output volatility is reported directly, while consumption, investment, government spending, employment and Solow residual volatility are expressed relative to output volatility. Following BKK, the standard deviation of the net exports-to-output ratio is also reported directly. The second column of Table 5 gives GDP's one-quarter autocorrelation; the remaining columns give its contemporaneous correlation with each variable.

y and nx: standard deviations (%). Remaining columns: ratio to output volatility.

Country	y	nx	c	x	g	n	z
AUS	1.32 (1.45)	1.14 (1.23)	.83 (.66)	2.98 (2.78)	1.28 (1.28)	.79 (.34)	.77 (1.00)
AUT	1.24 (1.28)	.80 (1.15)	.94 (1.14)	2.65 (2.92)	.68 (.36)	.67 (1.23)	.97 (.84)
CAN	1.36 (1.50)	.88 (.78)	.81 (.85)	2.94 (2.80)	1.04 (.77)	.77 (.86)	.70 (.74)
CHE	1.66 (1.92)	1.89 (1.32)	.64 (.74)	2.35 (2.30)	.92 (.53)	— (.71)	— (.67)
DEU	1.58 (1.51)	.70 (.79)	.77 (.90)	2.57 (2.93)	.86 (.81)	.67 (.61)	.84 (.83)
EU15	1.07 (1.01)	.43 (.50)	.72 (.83)	2.43 (2.09)	.53 (.47)	— (.85)	— (.98)
FRA	1.12 (.90)	.62 (.82)	.79 (.99)	2.30 (2.96)	.58 (.71)	.49 (.55)	.73 (.76)
GBR	1.48 (1.61)	.88 (1.69)	1.08 (1.15)	2.58 (2.29)	.84 (.69)	.65 (.68)	.84 (.88)
ITA	1.46 (1.69)	1.00 (1.33)	.87 (.78)	2.56 (1.95)	.58 (.42)	.48 (.44)	.94 (.92)
JPN	1.56 (1.35)	.79 (.93)	.79 (1.09)	2.22 (2.41)	.74 (.79)	.33 (.36)	.92 (.88)
USA	1.63 (1.92)	.43 (.52)	.77 (.75)	2.48 (3.27)	.84 (.75)	.64 (.61)	.65 (.68)

Original 2015 publication values. Parentheses: BKK (1993). Square brackets: ACZ (2004). A dash denotes an unavailable estimate.

Table 4: Standard Deviations

Country	Autocorr.	c	x	g	nx	n	z
AUS	.70 (.60)	.44 (.46)	.66 (.68)	.00 (.15)	-.26 (-.01)	.56 (.12)	.84 (.98)
AUT	.72 (.57)	.54 (.65)	.68 (.75)	-.05 (-.24)	-.12 (-.46)	.29 (.58)	.91 (.65)
CAN	.83 (.79)	.78 (.83)	.69 (.52)	-.21 (-.23)	.05 (-.26)	.76 (.69)	.89 (.84)
CHE	.83 (.90)	.70 (.81)	.78 (.82)	.34 (.27)	-.23 (-.68)	— (.84)	— (.93)
DEU	.78 (.65)	.63 (.66)	.84 (.84)	-.06 (.26)	-.06 (-.11)	.58 (.59)	.91 (.93)
EU15	.86 (.75)	.80 (.81)	.91 (.89)	-.20 (.10)	-.34 (-.25)	— (.32)	— (.85)
FRA	.55 (.78)	.68 (.61)	.83 (.79)	-.03 (.25)	-.11 (-.30)	.58 (.77)	.93 (.96)
GBR	.80 (.63)	.77 (.74)	.74 (.59)	-.08 (.05)	-.35 (-.19)	.62 (.47)	.92 (.90)
ITA	.82 (.85)	.69 (.82)	.79 (.86)	-.04 (.01)	-.48 (-.68)	.33 (.42)	.95 (.96)
JPN	.78 (.80)	.75 (.80)	.86 (.90)	.07 (-.02)	-.20 (-.22)	.46 (.60)	.98 (.98)
USA	.85 (.86)	.77 (.82)	.92 (.94)	-.13 (.12)	-.35 (.-37)	.77 (.88)	.92 (.96)

Original 2015 publication values. Parentheses: BKK (1993). Square brackets: ACZ (2004). A dash denotes an unavailable estimate.

Table 5: Within-country Correlation between Output and other Variables

Our results broadly conform to the stylized facts of business cycles. Consumption is procyclical and, except in the United Kingdom, less volatile than output. In BKK's sample, consumption was more volatile than output in three countries. Relative consumption volatility falls in eight of the eleven countries in our sample. Of the three where it rises, only Australia records an increase greater than 0.1.

Investment is also procyclical, but more volatile than output. Its relative volatility ranges from 2.22 in Japan to almost three in Australia. Unlike consumption, investment shows no clear overall change in relative volatility between BKK's sample and ours. The US ratio falls sharply, from 3.27 to 2.48. Together with an increase in Italy, this narrows the range of relative investment volatility across countries from 1.32 to 0.72.

Output autocorrelation changes little: it rises in six countries and falls in five, generally by modest amounts. Output volatility likewise falls in six countries and rises in five. Its distribution becomes less dispersed, however. Countries with relatively high output volatility, including the United States, Switzerland and Italy, generally experience declines, while countries with lower volatility, including France, the European aggregate and Japan, experience increases.

Government spending shows no clear cyclical pattern. Its correlation with output is negative in most countries in our sample, but generally small. The largest correlation in absolute value is positive: 0.34 for Switzerland. These results suggest that government spending is broadly acyclical. BKK's correlations are mostly positive but no larger than 0.27 in absolute value, which is also consistent with weak cyclicality.

Employment volatility and its correlation with output change considerably in some countries, but the overall pattern remains similar. Solow residual volatility also rises in some countries and falls in others. There is no clear overall shift in the comovements of employment or Solow residuals with output.

4.2 International Comovements with the United States

We now turn from within-country patterns to international comovements. Following BKK, we use the United States as a benchmark and calculate the contemporaneous correlation of each US variable with its counterpart in the other ten countries. Table 6 reports these correlations.

As in BKK, all output correlations are positive, but nine of the ten are smaller in our sample. Only the United Kingdom shows a slight increase in its correlation with US output. Lower output correlations bring the data closer to the model's predictions.

Consumption also follows a pattern similar to BKK's. In our longer sample, US consumption is positively correlated with consumption in every country except Italy. In BKK's sample, Australia is the sole exception. Consumption correlations generally decline, although the pattern is less clear than for output. This decline widens the gap between the model and the data, since the benchmark model predicts a high consumption correlation of 0.88.

The international comovements of investment and government spending change little overall. US investment remains positively correlated with investment in every other sample country, although the range of these correlations narrows from 0.57 to 0.39. Government spending remains only weakly correlated across countries.

Net exports are weakly correlated between the United States and the other countries, with a slight tendency toward negative correlations. BKK do not report cross-country net export correlations.

Employment correlations between the United States and the other countries are positive in both our sample and BKK's. US Solow residuals also remain positively correlated with those of every other country, although the correlations are generally smaller.

Extending BKK's calculations with 23 additional years of data leaves their main conclusion intact. Output and consumption correlations decline on average, but the quantity anomaly concerns their relative magnitudes. Because both decline, their ranking remains largely unchanged, and the anomaly persists.

Country	y	c	x	g	nx	n	z
AUS	.27 (.51)	.02 (.-19)	.36 (.16)	.07 (.23)	.05	.37 (-.18)	.28 (.52)
AUT	.28 (.38)	.17 (.23)	.33 (.46)	.09 (.29)	.09	.27 (.47)	.24 (.17)
CAN	.75 (.76)	.56 (.49)	.35 (-.01)	.33 (-.01)	-.31	.60 (.53)	.63 (.75)
CHE	.30 (.42)	.21 (.40)	.38 (.38)	-.03 (.01)	-.11	— (.36)	— (.43)
DEU	.37 (.69)	.30 (.49)	.42 (.55)	.05 (.28)	-.04	.37 (.52)	.31 (.65)
EU15	.53 (.66)	.44 (.51)	.51 (.53)	.23 (.18)	-.11	— (.33)	— (.56)
FRA	.36 (.41)	.29 (.39)	.35 (.22)	-.03 (-.20)	.04	.16 (.26)	.37 (.39)
GBR	.59 (.55)	.45 (.42)	.44 (.40)	.21 (-.04)	.01	.67 (.69)	.50 (.35)
ITA	.32 (.41)	-.03 (.02)	.12 (.31)	.14 (.09)	-.16	-.01 (-.01)	.24 (.35)
JPN	.32 (.60)	.22 (.44)	.35 (.56)	.03 (.11)	-.22	.41 (.32)	.20 (.58)

Original 2015 publication values. Parentheses: BKK (1993). Square brackets: ACZ (2004). A dash denotes an unavailable estimate.

Table 6: Cross-country Correlations

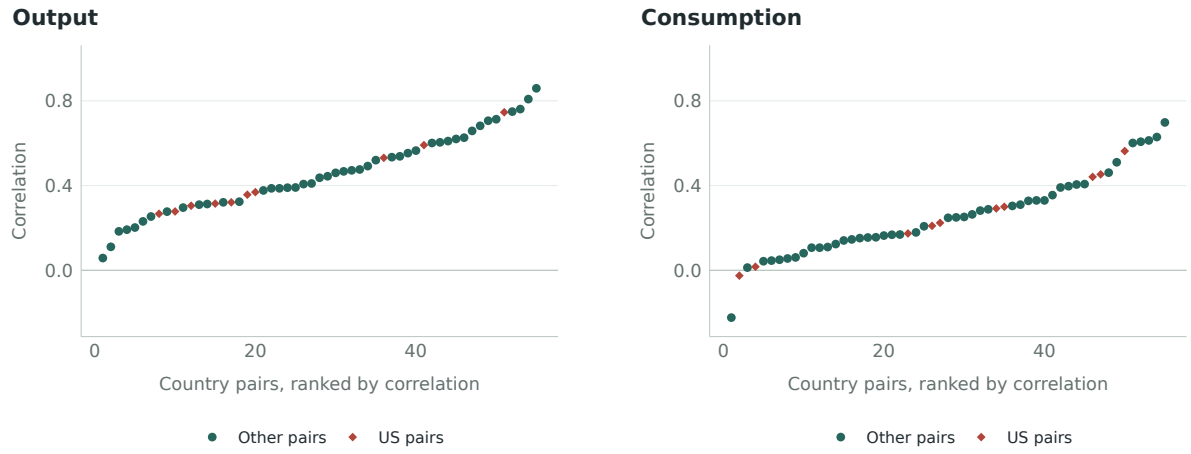
4.3 International Comovements across All Countries

BKK report only international correlations involving the United States, leaving out the other 45 country pairs in their eleven-country sample. As Ambler et al. (2004) argue, the United States is not representative of industrialized economies in either size or openness. Correlations involving the United States may therefore provide an incomplete picture of international comovements.

To assess how representative US correlations are, we examine all 55 country pairs. This includes, for example, the Germany–Japan correlation as well as each country's correlation with the United States.

Figure 2 plots output and consumption correlations in ascending order, highlighting pairs involving the United States. We focus on these two variables because their relative correlations define the quantity anomaly.

All output correlations are positive, and those involving the United States are smaller on average than the others. Consumption correlations are also positive except for Italy–United States and Australia–Germany. US consumption correlations are more evenly distributed across the range of pairwise correlations.



(a) Output correlations (b) Consumption correlations

Figure 2: Output and Consumption Correlations among all Countries

We next summarize international comovements using the mean correlation across all country pairs. Comparing this with the mean for US pairs shows how much the choice of benchmark matters. Ambler et al. (2004), hereafter ACZ, use a similar approach.[10] Table 7 reports the mean across all pairs in its first column, the mean for US pairs in its second, and selected quantiles in the remaining columns. We compare these summaries with ACZ's findings below.

Variable	Mean	US mean	0%	10%	25%	40%	50%	60%	75%	90%	100%
y	.45 [.22]	.41 (.54)	.06	.23	.31	.39	.44	.48	.60	.71	.86
c	.26 [.14]	.26 (.32)	-.22	.05	.12	.17	.25	.29	.39	.56	.70
x	.38 [.18]	.36 (.36)	.01	.15	.24	.32	.37	.42	.51	.61	.83
g	.10	.11 (.35)	-.28	-.07	-.03	.05	.07	.11	.15	.33	.78
nx	.08	-.08	-.31	-.22	-.08	.02	.05	.09	.20	.41	.75
n	.28 [.20]	.36 (.32)	-.04	.02	.10	.20	.26	.32	.41	.61	.69
z	.35 [.16]	.34 (.48)	-.02	.14	.22	.32	.35	.38	.47	.51	.72

Original 2015 publication values. Parentheses: BKK (1993). Square brackets: ACZ (2004). A dash denotes an unavailable estimate.

Table 7: Average Cross-country Correlation among all Countries

Similar means and medians indicate that the choice between these summaries has little effect on the overall pattern. The quantiles also suggest that the quantity anomaly persists. Half of the output corre-

[10] ACZ reassess BKK's results using twenty industrialized countries and data from 1960:1 to 2000:4. Unlike BKK, they include capital when calculating Solow residuals. They also report standard errors and test the statistical significance of their results.

lations exceed approximately 0.44, while no consumption correlation reaches the benchmark model's prediction of 0.88. The largest consumption correlation is 0.70, and 90% lie below approximately 0.56.

Averaging only US pairs produces results close to the averages across all country pairs. Excluding net exports,[11] the largest difference between the two means is 0.07, for civilian employment. Compared with BKK, US correlations decline for all reported variables except investment and employment. Mean output correlation falls by 0.13 and mean consumption correlation by 0.06.

These declines are smaller than those reported by ACZ. Their mean output correlation falls from BKK's 0.54 to 0.22, moving the data closer to models that predict low or negative output correlations. Their mean consumption correlation falls by 0.18, widening the discrepancy with the high consumption correlations predicted by the model.

Our estimates lie between BKK's and ACZ's. ACZ's larger country sample may help explain their lower correlations. Extending the sample period also reduces measured correlations in our analysis, although by less than the differences reported by ACZ.

The overall decline in correlations has little effect on the quantity anomaly. Lower output correlations bring the data closer to the model, while lower consumption correlations move them farther away. The discrepancy in their relative magnitudes remains.

The quantity anomaly is especially clear when country pairs are examined individually. Figure 3 plots output correlation against consumption correlation for all 55 pairs. The 45-degree line has a slope of one and marks equality between the two correlations. Only Australia–France and Switzerland–United Kingdom lie below it. In the remaining pairs, output is more highly correlated than consumption.

[11]The US trade balance may behave differently because of the dollar's role as an international reserve currency. US foreign investments earn returns two to three times higher than the rates paid on US liabilities to foreign investors. This advantage can help finance persistent trade deficits and may make US net export comovements less representative of other country pairs. For a discussion of the "exorbitant privilege", see Eichengreen (2011).

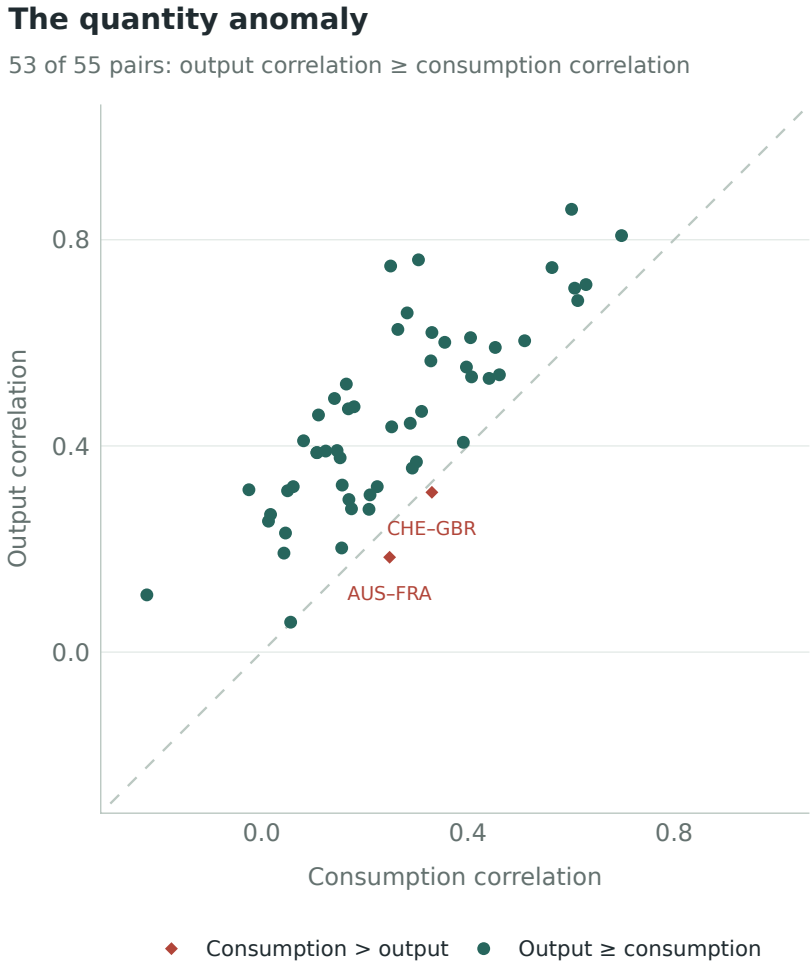


Figure 3: Cross-country Correlation of Output and Consumption for each Pair of Countries

The gap between output and consumption correlations is roughly 0.20 in both BKK's results and ours. ACZ find a smaller gap of 0.08, but reject the null hypothesis that average output correlation is no greater than average consumption correlation, $H_0 : \rho_{y,y^*} \leq \rho_{c,c^*}$, at the 5% significance level. Our pairwise comparison reinforces this finding: output correlation exceeds consumption correlation in 53 of the 55 country pairs.

4.4 Further Research on International Business Cycles

Two subsequent studies illustrate how changes to financial-market assumptions can address parts of the quantity anomaly.

Kehoe and Perri (2002) address the problem of negative cross-country output correlation by allowing countries to default on their loans. Repayment is enforced only by the threat of exclusion from future trade. This credit-market friction produces a positive output correlation of 0.25, although it remains below the consumption correlation of 0.29.

Faia (2007) challenges the view that trade is the central driver of international comovements and emphasizes the role of financial institutions. She finds a negative relationship between pairwise output correlation and a measure of financial distance. Her model introduces financial frictions and reproduces positive cross-country comovements in output, investment and employment.

Other studies use different methods to analyze international business cycles. Kose et al. (2003) apply a Bayesian method to annual data from 60 countries, separating fluctuations into world, regional and country-specific factors. They find that the common world factor explains an important share of

business cycle variation. Stock and Watson (2003) use a structural vector autoregression (VAR) model[12] to explain the decline in volatility among G7 economies over the preceding two decades, attributing it to smaller common international shocks. Fund (2010) also use a structural VAR to examine the role of US financial shocks in international business cycles.

These studies illustrate the range of methods available for studying international business cycles. Structural VARs and other econometric techniques can address questions that extend beyond the descriptive analysis of cross-country comovements undertaken here.

[12]Webb (1999) provides an accessible introduction to VAR models.

5 Conclusion

We reassess BKK's findings on international business cycles using 23 additional years of data. Standard deviations and within-country comovements change relatively little, while cross-country correlations decline for most variables.

Correlations involving the United States provide a summary close to that obtained from all country pairs. In this sample, its distinctive size and degree of openness do not substantially distort the summary of international comovements.

Our mean correlation estimates lie between BKK's and ACZ's. The lower correlations reported by ACZ may owe more to their larger country sample than to the length of their time series.

The quantity anomaly persists. Output correlation exceeds consumption correlation in 53 of the 55 country pairs. All output correlations are positive, in contrast to the negative correlation predicted by the benchmark model. No consumption correlation reaches the model's prediction of 0.88.

Lower international correlations therefore do not resolve the quantity anomaly. Output and consumption correlations both decline, but their relative ranking remains largely unchanged.

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A Aspects of the Data

A.1 Selection of the Measure

Selecting an appropriate measure was an important step in assembling the data. The OECD's *National Accounts* offers 27 measures, of which 20 are potentially relevant for the levels of the variables studied here. The remaining seven concern growth or population.

BKK do not specify their chosen measure. They state only that the variables are measured in real terms, except for the net exports-to-output ratio, which uses current prices.

We used three steps to select a comparable measure:

1. We downloaded output data from the OECD website in every available measure.
2. We used R to calculate output correlations between the United States and the ten other BKK countries for each measure.
3. We compared the results with BKK's and selected the closest comparable measure.

Over the full period from 1947:1 to 2015:2, nine measures provide enough observations to calculate output correlations between the United States and the other sample countries. Restricting the comparison to BKK's period, 1970:1 to 1990:2, leaves four measures. Table 8 reports the resulting US output correlations alongside those from BKK and ACZ.

Measure	AUS	AUT	CAN	CHE	DEU	FRA	GBR	ITA	JPN	USA
BKK (1993)	.51	.38	.76	.42	.69	.41	.55	.41	.60	1.00
ACZ (2004)	.40	.32	.77	.35	.50	.27	.68	.33	.39	1.00
CARSA	.00	.08	.29	.11	.29	−.14	−.01	−.04	.22	1.00
CPCARSA	.27	−.00	.56	.26	.41	.11	.30	.24	.38	1.00
VOBARSA	.35	.29	.71	.41	.66	.39	.62	.37	.60	1.00
VPVOBARSA	.35	.29	.71	.41	.66	.39	.62	.37	.60	1.00

Table 8: Cross-country Correlation of US Output in Four Different Measures, 1970:1–1990:2

We exclude CARSA and CPCARSA because they measure output at current prices, whereas BKK use real values. Their correlations also differ substantially from BKK's.

VOBARSA and VPVOBARSA produce identical correlations and are the closest to both BKK's and ACZ's estimates. They differ only in scale: VOBARSA is expressed in national currency, while VPVOBARSA is expressed in US dollars. Scaling a series by a positive constant leaves its correlations unchanged. For our analysis of HP-filtered log values, a fixed currency conversion adds only a constant to the log series and therefore leaves the cyclical component unchanged. We choose VPVOBARSA so that output levels are also expressed in a common unit.

A.2 Civilian Employment Series

BKK obtain quarterly civilian employment data from the OECD's *Main Economic Indicators*. At the time of data collection, these series were unavailable on the OECD website, which instead provided quarterly employed-population data through its *Short-Term Labour Market Statistics*. As Table 9 shows, some of these series are too short for a useful comparison with BKK. The Federal Reserve Bank of St. Louis website[13] provides the *Main Economic Indicators* series for France, the United Kingdom and Italy, allowing us to extend their coverage. We could not find comparable series for Switzerland or the European aggregate, so we exclude them from the employment comovement calculations.

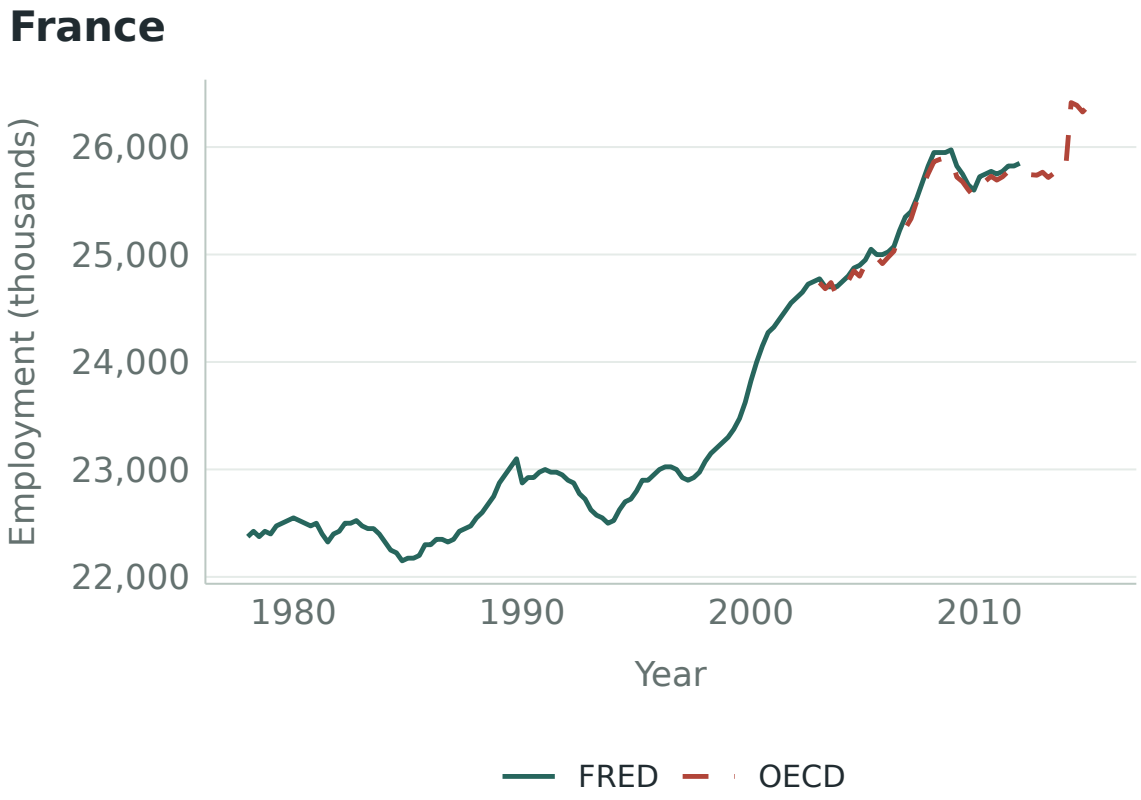
[13] https://research.stlouisfed.org/

Country	First quarter	Last quarter
AUS	1967:1	2015:2
AUT	1969:1	2015:1
CAN	1955:1	2015:2
FRA	2003:1	2015:1
DEU	1962:1	2015:1
ITA	1998:1	2015:1
JPN	1955:1	2015:2
CHE	1998:2	2015:1
GBR	1999:2	2015:1
USA	1955:1	2015:2
EA19	2005:1	2015:1

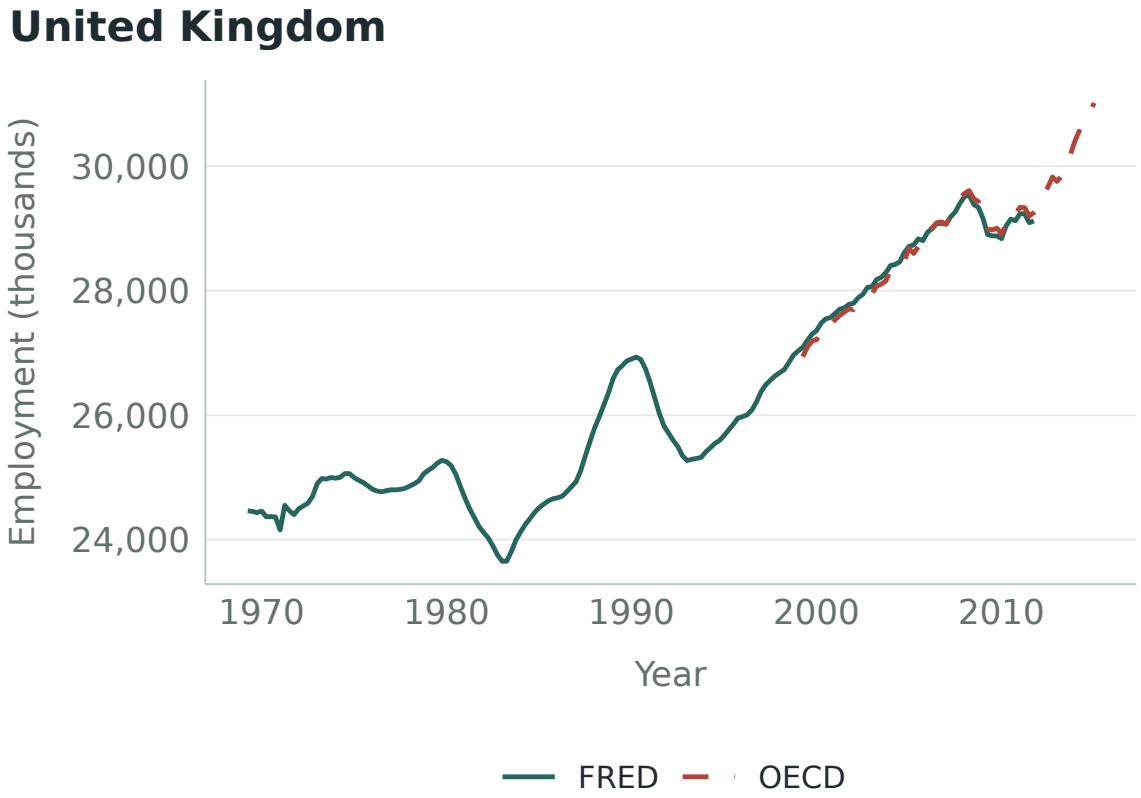
Table 9: Length of Employed Population Series from Short-Term Labour Market Statistics

Figure 4 compares the employment series from the two sources. Their similar behavior supports splicing them to obtain longer series for France, the United Kingdom and Italy. We rescale the *Short-Term Labour Market Statistics* series so that it matches the *Main Economic Indicators* series at the splice point, then use it to extend the earlier series. Table 3 reports the coverage of the resulting series.

France



United Kingdom



Italy

Figure 4: Civilian Employment Series

Italy

Declaration of Authorship

I hereby confirm that I have authored this Bachelor's thesis independently and without use of others than the indicated sources. All passages which are literally or in general matter taken out of publications or other sources are marked as such.

Berlin, September 5, 2015
Denis Augusto Pinto Maciel