Business cycles and Patenting

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Outline

- Motivation

- Method & Framework

- Data & Sample Statistics

- Results

- Discussion

Motivation: Why Business Cycles Matter

- Relevance for:
    - ➢Academic Research
        - Is Innovation driven more by long term (LT) or short term (ST) factors? And if ST, is R&D/Patenting pro-cyclical or counter-cyclical?
    - ➢International Organizations
        - Policy and Planning

- Our Contribution:
    - ➢Separate Cycles from Trend
        - Utilize measures of cyclical shocks (Intensity and Timing)
    - ➢Panel Data Analysis

FRAMEWORK: BUSINESS CYCLES FOR GDP (Y)

$Y = Y^T + Y^C$ ⟵ via the Hodrick-Prescott (HP) Filter Method

where Y^T is the trend level of output

   Y^C is the cyclical component of output.

The trend component is positive, but the cyclical component

can be positive or negative.

The natural log of Y then is $\ln Y = \ln (Y^T + Y^C) = \ln(Y^T(1+\frac{Y^C}{Y^T})) = \ln(Y^T) + \ln(1+\frac{Y^C}{Y^T})$.

The business cycle variable is $u = \dfrac{Y^C}{Y^T}$

Then, since Y^C/Y^T is small, assume that $\ln (1 + u) \approx u$

ECONOMETRIC MODEL FOR PATENT FILINGS WITH BUSINESS CYCLES

$$\ln\left(\frac{P}{L}\right)_{it} = \alpha_i + \alpha_1 \ln\left(\frac{P}{L}\right)_{it-1} + \alpha_2 \ln\left(\frac{P}{L}\right)_{it-2} + \alpha_3 \ln\left(\frac{R}{L}\right)_{it} + \alpha_4 \ln\left(\frac{Y^T}{L}\right)_{it} + \alpha_5 u_{it} + \alpha_t + \varepsilon_{it}$$

where P is the number of EPO Total filings from a source country;
L is the number of workers in the source country;
$_i$ is the source country and $_t$ is time (years);
$_{-1}$ and $_{-2}$ indicate lags of one year and two years respectively;
R is R&D expenditures, sometimes lagged;
The GDP of the source country Y is split into two components:-
$\qquad$ Y^T is the "trend" level of output
$\qquad$ u is the business cycle variable;
α terms are estimable parameters (α_t is a trend term over time);
ε is an error term, assumed to be normal with constant variance;
ln( ) denotes natural logarithm.

Estimation by System Two-Step GMM

Data

Variable	Data Sources
Patenting	• European Patent Office (EPO), EPASYS • World Intellectual Property Organization (WIPO), http://www.wipo.int/ipstats/en/statistics/pct/
Gross Domestic Product	• World Bank, *World Development Indicators* http://data.worldbank.org/data-catalog/world-development-indicators
Business Research and Development Funding (R&D)	• Organization for Economic Cooperation and Development (OECD) www.oecd-ilibrary.org • United Nations Educational, Scientific and Cultural Organization (UNESCO) http://stats.uis.unesco.org/unesco/ReportFolders/ReportFolders.aspx?IF_ActivePath=P,54&IF_Language=eng
Labor	• World Bank, *World Development Indicators* http://data.worldbank.org/data-catalog/world-development-indicators
Unemployment Rates	• World Bank, *World Development Indicators* http://data.worldbank.org/data-catalog/world-development-indicators • International Monetary Fund (IMF), *International Financial Statistics*, http://elibrary-data.imf.org/
Exchange Rates, PPP Conversion	• Penn World Tables https://pwt.sas.upenn.edu/ • International Monetary Fund (IMF), *International Financial Statistics*, http://elibrary-data.imf.org/ • Organization for Economic Cooperation and Development (OECD) www.oecd-ilibrary.org

Figure 1. Business Cycle Index (u): Selected Countries

France — Germany — Japan — U.K. — U.S.A.
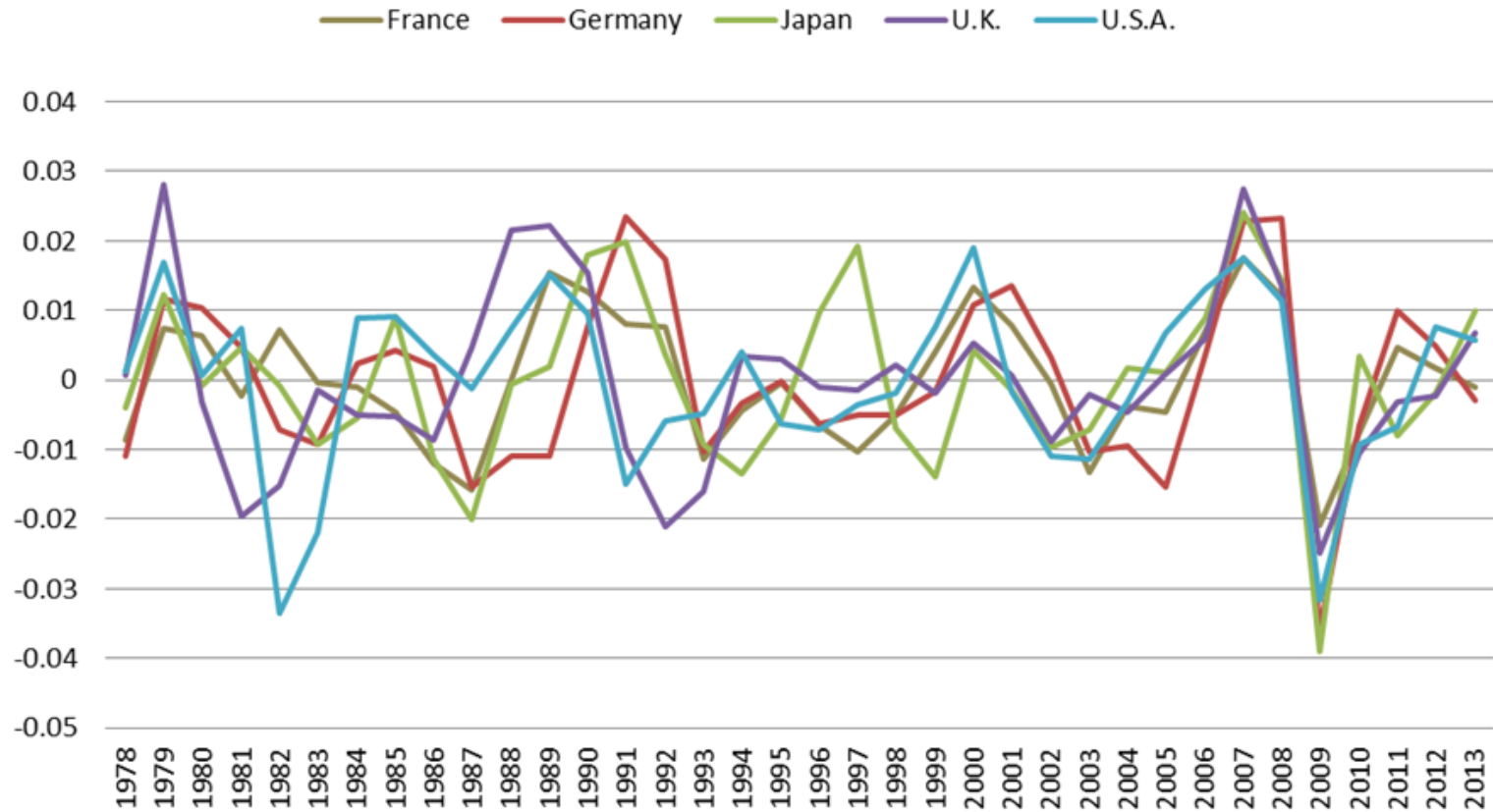
Figure 2. European Patent Office (EPO) Patent Filings: Direct plus Euro via PCT International Phase Filings
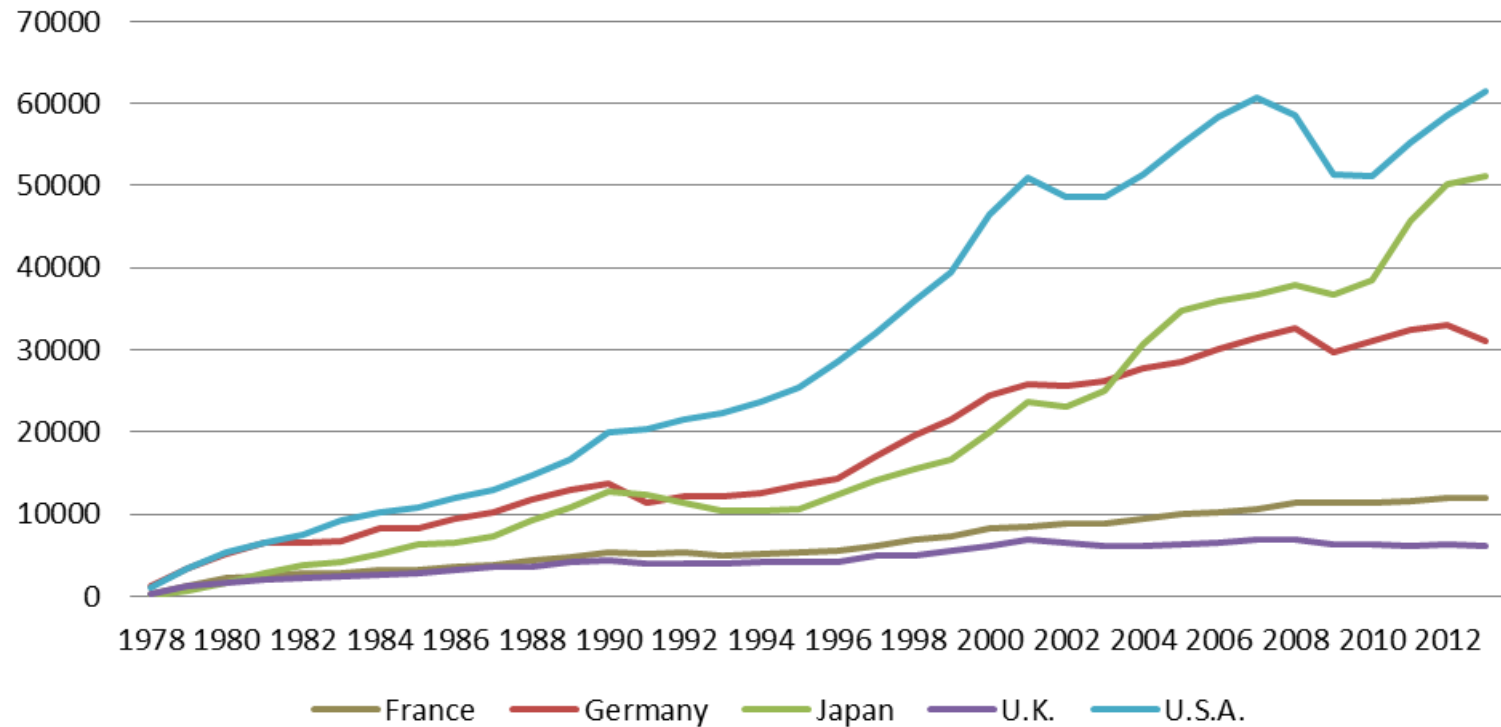
RESULTS – u IS GENERALLY SIGNIFICANT

Table 3. Impact of Business Cycles on European Patent Office (EPO) Filings -- Per Worker

Dependent Variable: pl = ln(EPO Filings/Labor)

VARIABLES	(1) pl	(2) pl	(3) pl	(4) pl	(5) pl	(6) pl	(7) pl	(8) pl	(9) pl	(10) pl
Type of Sample	Full	Full	1998-2013	1978-1997	Full	Full	Full	1998-2013	1978-1997	Full
L.pl	0.760***	0.806***	0.737***	0.580***	0.758***	0.730***	0.742***	0.782***	0.596***	0.568***
	(0.030)	(0.034)	(0.030)	(0.033)	(0.052)	(0.067)	(0.079)	(0.038)	(0.049)	(0.111)
L2.pl	0.060***	0.071***	0.022	0.121***	0.072***	0.071***	0.061*	0.003	0.093***	0.089**
	(0.010)	(0.012)	(0.017)	(0.017)	(0.013)	(0.021)	(0.036)	(0.019)	(0.027)	(0.039)
ln (Real GDP/Labor)	0.512***					0.581**				
	(0.129)					(0.284)				
u		1.327***	1.155***	2.071***	1.024***		1.062***	1.437***	1.453**	0.742***
		(0.242)	(0.198)	(0.204)	(0.176)		(0.392)	(0.239)	(0.620)	(0.278)
ln (Real Trend GDP/Labor)		0.427***	0.298***	1.050***	0.549***		0.539	0.380*	0.887***	1.150***
		(0.136)	(0.099)	(0.180)	(0.184)		(0.335)	(0.229)	(0.158)	(0.412)
ln (BERD/Labor)	0.056	-0.013	0.159**	-0.010		0.089	0.110	0.111	0.041	
	(0.058)	(0.095)	(0.066)	(0.088)		(0.082)	(0.161)	(0.077)	(0.131)	
u_BERD					0.300**					0.878***
					(0.145)					(0.258)
ln (BERD Trend/Labor)					0.038					0.152
					(0.079)					(0.148)
Constant	-7.453***	-5.563***	-6.288***	-13.981***	-7.635***	-8.551**	-8.218**	-6.647***	-12.656***	-16.400***
	(1.625)	(1.430)	(0.966)	(2.009)	(2.532)	(3.433)	(3.945)	(2.226)	(1.965)	(5.179)
Time Dummies	Excluded	Excluded	Excluded	Excluded	Excluded	Included	Included	Included	Included	Included
AB Test (p-value)	0.71	0.82	0.80	0.62	0.79	0.77	0.69	0.65	0.91	0.96
SH Test (p-value)	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Goodness of Fit	0.98	0.98	0.98	0.98	0.98	0.96	0.98	0.98	0.96	0.97
Observations	950	950	448	502	950	950	950	448	502	950

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The full sample is over the period 1978 - 2013. The estimation method is System Generalized Method of Moments (GMM). The AB test is the Arellano-Bond test of no 2nd-order autocorrelation in the first differences of the residuals and the SH test is the Sargan-Hansen Overidentification Test of no correlation between the instruments and the error term. The Goodness of Fit is the squared correlation coefficient between the predicted and actual value of the dependent variable. BERD refers to Business Enterprise R&D, and Labor to the number of workers. L and L2 are the first and second lag operator.

SENSITIVITY CHECK: RESULTS DRIVEN BY 2009?

Table 6. Sensitivity to a Financial Crisis 2009 Effect

Dependent Variable: pl = ln(EPO Filings/Labor)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	pl	pl	pl	pl	pl	pl
Type of Sample	Full	Full	Full	Full	Full	Full
L.pl	0.802***	0.808***	0.783***	0.771***	0.800***	0.793***
	(0.030)	(0.038)	(0.030)	(0.031)	(0.037)	(0.026)
L2.pl	0.081***	0.064***	0.079***	0.070***	0.081***	0.073***
	(0.015)	(0.012)	(0.008)	(0.008)	(0.016)	(0.020)
yl	0.449***	0.569***	0.317*	0.444**	0.448***	0.376***
	(0.147)	(0.182)	(0.186)	(0.212)	(0.150)	(0.059)
rl	-0.054	-0.071	0.066	0.080	-0.051	0.013
	(0.064)	(0.096)	(0.095)	(0.098)	(0.081)	(0.036)
Dummy for 2009	-0.043***	-0.054***			-0.083	-0.054
	(0.007)	(0.009)			(0.504)	(0.082)
u	1.149***	1.127***	1.179***	1.046***	1.153***	0.940*
	(0.178)	(0.282)	(0.252)	(0.269)	(0.187)	(0.552)
Dummy for 2009 x u			0.936***	1.441***	-1.616	-0.037
			(0.361)	(0.452)	(20.412)	(2.676)
Time Trend		0.000		-0.001		0.001
		(0.003)		(0.002)		(0.001)
Constant	-5.513***	-7.258*	-5.008***	-4.592	-5.530***	-7.979**
	(1.614)	(4.265)	(1.928)	(3.914)	(1.624)	(3.269)
Country Fixed Effects	Included	Included	Included	Included	Included	Included
AB Test (p-value)	0.88	0.77	0.87	0.81	0.88	0.77
SH Test (p-value)	0.99	0.99	0.99	0.99	0.99	0.99
Goodness of Fit	0.98	0.98	0.98	0.98	0.98	0.96
Observations	950	950	950	950	950	950

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Dummy for 2009 = 1 for the year 2009 and zero otherwise. No other time dummies included. See also Notes to Table 3.

Experiment

- Estimate the model up to 2005

- Estimate AR2 models of Trend GDP and the Business Cycle Index (u), also up to 2005

- Use their fitted values to generate forecasts for 2006 – 2013

- Root Mean Square Percentage Error (RMSPE) is used as the measure of forecast accuracy

Table 8. Out of Sample Filing Forecasts -- Forecast Accuracy

Assumptions for 2006 - 2013:	Case 1 Actual Trend, Actual Cycle	Case 2 Actual Trend, No Cycle	Case 3 Forecasted Trend, Actual Cycle	Case 4 Forecasted Trend, No Cycle	Case 5 Forecasted Trend, Forecasted Cycle	Case 6 Forecasted Trend, Forecasted Cycle, Shock in 2009
year	RMPSE	RMPSE	RMPSE	RMPSE	RMPSE	RMPSE
2006	0.095	0.119	0.096	0.119	0.105	0.105
2007	0.100	0.119	0.101	0.122	0.105	0.105
2008	0.119	0.125	0.119	0.126	0.122	0.122
2009	0.142	0.159	0.144	0.160	0.154	0.143
2010	0.128	0.133	0.130	0.136	0.130	0.136
2011	0.120	0.132	0.125	0.142	0.127	0.120
2012	0.114	0.120	0.114	0.129	0.123	0.123
2013	0.102	0.110	0.124	0.139	0.136	0.135
Total	0.115	0.127	0.119	0.134	0.125	0.124

Notes: Model Estimated up to 2005 is used to forecast filings during 2006 - 2013. The actual R&D per worker is assumed during the out of sample period. The assumed path of trend GDP and index of business cycles u are given in the table. RMPSE denotes root mean percentage squared error. In case 6, the shock in 2009 equals three times a country's largest adverse business cycle, u, value during 1978-2005.

Table 9. Out of Sample Filing Forecasts -- Predicted Means and Standard Errors

		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
	Assumptions for 2006 - 2013:	Actual Trend, Actual Cycle	Actual Trend, No Cycle	Forecasted Trend, Actual Cycle	Forecasted Trend, No Cycle	Forecasted Trend, Forecasted Cycle	Forecasted Trend, Forecasted Cycle, Shock in 2009
year	Actual Filings	Predicted	Predicted	Predicted	Predicted	Predicted	Predicted
2006	203940	203347 (3629.6)	194761 (2399.6)	203602 (3625.1)	195038 (2408.3)	196444 (2918.7)	196444 (2918.7)
2007	215493	224476 (4103.3)	208833 (2661.8)	224552 (4118.2)	204522 (2649.6)	209472 (3112.7)	209472 (3112.7)
2008	218756	234555 (4140.0)	221708 (2920.3)	234261 (4182.1)	217886 (2883.0)	221775 (3297.1)	221775 (3297.1)
2009	204609	215527 (3596.4)	223292 (2791.6)	214733 (3676.6)	231945 (2716.8)	223513 (3366.8)	210992 (3331.3)
2010	214482	217567 (3580.3)	213217 (2779.5)	216265 (3749.7)	250647 (2691.0)	212736 (3256.1)	205251 (3238.2)
2011	234324	232879 (3902.1)	224130 (2970.0)	230904 (4185.7)	275931 (2857.1)	223196 (3360.8)	223211 (3382.4)
2012	248165	253063 (4209.0)	244906 (3220.8)	250493 (4605.4)	308279 (3078.7)	243662 (3685.0)	247846 (3742.7)
2013	257457	263750 (4242.8)	258710 (3407.0)	259950 (5061.2)	350082 (3295.1)	256352 (4200.8)	259826 (4226.5)
Total	1797226	1845164 (11128.7)	1789557 (8227.6)	1834759 (11811.6)	1778741 (8015.8)	1787148 (9671.5)	1774815 (9694.1)

Notes: Model Estimated up to 2005 is used to forecast filings during 2006 - 2013. The actual R&D per worker is assumed during the out of sample period. The assumed path of trend GDP and index of business cycles u are given in the table. Standard errors of predictions are in parentheses. In case 6, the shock in 2009 equals three times a country's largest adverse business cycle, u, value during 1978-2005.

CONCLUSIONS

Forecasting patents valuable for Institutions (Patent Offices) and Multinational Businesses

Patent filings decisions respond <u>procyclically</u> to GDP shocks.

Forecasting cycles adds 'value' to forecasts of trends (in terms of forecast accuracy).

'Tinkering' cyclical forecasts does not add value

The results suggests that quite large disruptions to GDP need not have large or long lasting effects on numbers of patent filings.