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Oil Price Shocks, Financial Frictions and TFP Dynamics

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Marcella Lucchetta*, Antonio Paradiso⊥, Roberto Savona±

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Abstract

This work studies the interconnections between financial risks, oil price and TFP, exploring how oil and financial shocks affect productivity, and how technology moves from one country to another when oil shocks and financial frictions are factored in. Using data on the US, Germany, and France, we estimate a state-space model with time-varying parameters. Our results show that only after the second half of the 2000s, the effect of oil shocks on TFP was negative and statistically significant in France and the US. The sensitivity of financial frictions has decreased over time for the US, while there is an upward trend for France and Germany. Finally, exploring the technological spillover effects, we provide evidence that the US was ahead of France and Germany - in the aftermath of the crisis - and France was ahead of Germany - in the first half of 2000s.

Keywords: Systemic financial risk, Oil price, TFP growth, State space model.

JEL Classification: O47, G32.

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1. Introduction

Oil price shocks and financial frictions play an important role in macroeconomies, with disruptive effects on equilibrium dynamics. The oil price run-ups occurred in the first Persian Gulf War in 1990 and during the 2007-10 period were each followed by global economic recessions (Hamilton, 2009). Likewise, the events during the great liquidity and credit crunch of 2007-10 highlighted the importance of financial frictions for macroeconomics (Brunnermeier and Sannikov, 2014). A first question, therefore, is how do global risk factors, and specifically oil and financial shocks, affect productivity? Most of the empirical studies explore the response of output (or its potential) to both these shocks, whereas only a few authors examine their impacts on Total Factor Productivity (TFP). Kim and Loungani (1992) and Finn (1995) study the contribution of energy price shocks to business cycle dynamics. They conclude that energy price shocks account for up to 20 percent of real output volatility at business cycle frequencies. Using a SVAR approach, Blanchard and Gali (2007) estimate an impulse response function for different macro variables. They find that output declined persistently in the US before and after the Great Moderation period, whereas the effect was only significant in France and Germany in the period before the mid-1980s. More recently, Estrada and Hernández de Cos (2012) found a negative correlation between TFP and oil prices, using data from EU countries. Finally, Estevao and Severo (2014) investigated the impact of financial shocks (measured as changes in industries' funding costs) on productivity in the US and Canada. The authors find that increases in the cost of funds negatively affect TFP growth, showing a non-monotonic effect that depends on the sector's external finance.

A second question arises when considering the channels of international technology diffusion. This issue has been inspected in the literature (Keller, 2004), pointing to the international trade as the main transmission channel. How does technology move from one country to another when oil shocks and financial frictions are factored in? Answering this question helps us to understand the "pure" technological diffusion process in a globalised economic system, and to do this we have a live laboratory from the recent crisis of 2007-2010.

In this paper we handle both questions, inspecting how TFP dynamics for the US, Germany, and France are affected by oil price changes and financial systemic risk over the 1990-2014 period, and also exploring how technological gaps behave internationally. We have chosen to focus on France and Germany, because these two countries represent the Euro Area's two largest economies. By comparing these three economies, we would like to highlight some differences in technology promotion and the effects of oil and financial shocks between Euro Area and US. In our view, this is an interesting aspect that has been neglected by the previous literature.

Although we have built on Estevao and Severo (2014), as we look at how financial shocks spread through the real economy, our study is innovative in some important ways. Firstly, following De Nicolò and Lucchetta (2011), we implemented a different measure of financial systemic risk[1] based on the Market Adjusted Return (*MAR*), introduced in Campbell et al. (1997), as the difference between banking sector stock returns and total stock market returns. Secondly, in our model specification we also included oil price changes, which have been proven to be a main driver of the recent global economic downturn. Financial systemic risk factor and oil price are expected to play a key role in the technological innovation process of economies. On the one hand, a negative financial shock could translate into credit rationing, which in turns affects investments in R&D. On the other, a sudden increase in oil prices may force companies to cut investments in research as well, because of lesser inputs due to higher costs of production. Thirdly, within a state-space framework, we modelled TFP sensitivity to oil price and financial risk as time-varying coefficients. Exploring how the two global factors impact on productivity, and how their effects vary over time, can help us to understand the growth prospects in the medium- to long-run in a globalised economy. R&D and productivity are indeed strictly interconnected and it is well recognised that economic growth is significantly driven by improvements in productivity (Doraszelski and Jaumandreu, 2013). Finally, TFP innovations were then used to inspect international technological gaps, checking for global risk factors. The residual component of TFP we estimate is, in a sense, the idiosyncratic technological innovation choice of each country. Understanding how this component moves from country to country is important, as it identifies those countries which are technological leaders and those which are followers, checking for the impacts of global factors.

Our major empirical findings are as follows. The oil price-TFP relationship shows a negative value of the coefficient, thus confirming the pervasive effect of oil shocks on productivity, but

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[1] We use the expression “financial systemic risk”, “financial risks” and “financial frictions” interchangeably. This is because financial risks usually originate as financial frictions in the banking sector and affect the entire economy, potentially generating a systemic crisis. We explain this in more detail in Section 2.

with a difference in the pattern observed among countries. In particular, the coefficient was strengthening after the second half of the 2000s for France and for the US - even if the coefficient is only statistically significant after 2010 for the American economy. For Germany, sensitivity was negative and somewhat constant over the entire period, thereby indicating substantial oil-oriented firm productivity; the result for Germany is line with the evidence of Carstensen et al. (2013) evidence. Instead, the effect of *MAR* on TFP differed between France-Germany and the US: sensitivity decreased over time for the US, while there was an upward trend for France and Germany. The positive-to-negative *MAR* sensitivity for the US seems to contrast the common view on the importance of financial frictions for business cycles. This result is due to the following reasons: 1) The US has a market-oriented financial system, while France and Germany are more bank-oriented. Therefore, the bank losses occurring with the recent financial crisis of 2007-2010, impacted their clients and productivity for France and Germany, whereas losses were mitigated for US output (Gambacorta et al., 2014) thanks to more diversified financing channels. 2) US firms are technological leaders operating in competitive and global scenarios (Schwab and Sala-i-Martin, 2014) which look to innovation as the main driver to survive and excel in the long run, including during hard times when global crises occur.

Finally, we have investigated the technological spillover effects among the US, Germany and France, taking the residual component of TFP estimates after controlling for global factors (i.e. the cyclical component and the oil and financial markets dynamic). Our results led us to conclude that the US is ahead of France and Germany, in the aftermath of the crisis, and France was ahead of Germany= in the 2000-2005 period.

The paper is structured as follows. Section 2 discusses the connections among oil price shocks, financial frictions and TFP dynamics; Section 3 introduces the empirical model and Section 4 presents the results. Section 5 contains our conclusion.

2. Oil Price Shocks, Financial Frictions and TFP Dynamics

The nexus between oil price shocks and productivity has been fully addressed in the literature, emphasising different channels of transmissions impacting on real output. In Leduc and Sill (2004) the point is well discussed, proving that the more important factor is the direct effect of the oil-price increase on the negative output response. Oil enters the production function, after which, increases in its price lead to increases in the cost of production, which generally decrease the rhythm of economic activity (Cavalcanti and Jalles, 2013). The effect of a rise in oil price on productivity is explained particularly well in Peterson (2006). Higher oil price reduces productivity growth due to the reallocation resource process by firms; business companies redirect some resources from their best allocation to alternative use, i.e. the best possible use after the new price setting. In addition, firms have to pay for the more expensive oil and some resources are diverted from other uses; the result of this process is that some output will be lost and productivity will be reduced. However, other authors such as Olson (1988) postulate that the cost of energy corresponds to a small fraction of GDP and therefore oil price increases do not seem to account for this productivity slowdown.

Financial frictions originate with structural problems in the banking system and impact on credit supply conditions (rise in the cost of funding and/or credit crunch) thus amplifying and propagating real shock impacts on the economy. Much of the literature to date investigates the impacts on demand components (i.e. consumption and investment decisions), while little has been said about TFP and financial shocks. As pointed out by the Real Business Cycle (RBC) literature, technological shocks directly affect the TFP and its variations produce oscillations in GDP growth. Understanding how financial shocks impact TFP dynamics is then of crucial importance for both macroeconomists and policymakers. Using data on European firms, Levine and Warusawitharana (2014) provide evidence that financial development supports productivity growth within firms, which helps explain why economic activity remains persistently depressed following financial crisis. Millard and Nicolae (2014) argue that a rise in cost of funding may induce the firms to slow down R&D intensity with a negative impact on innovation and TFP growth. A similar argument occurs if we inspect the role of the banking system: huge losses in the banking sector may result in worse credit conditions, thereby producing a negative effect on the productivity enhancing projects of funding firms. Financial frictions affect investment and R&D spending (Hall, 2002; Hall and Lerner, 2009), also affecting the firm's ability to export (Greenaway et al., 2007). Gorodnichenko and Schnitzer (2013) find that financial constraints limit the ability of domestically owned firms to innovate and export and hence to catch up with the technological frontiers.

In our reasoning, TFP interconnections are affected by global factors (oil price shocks and financial frictions), then resulting in possible "pure" and "global factors-driven" technological spillovers. Recent developments in endogenous growth theory postulate that TFP growth is explained by innovative activity, educational attainment, distance to the frontier, the interaction between educational attainment and distance to the frontier, and knowledge spillovers through the channel of imports (Madsen, 2010). These are "pure" technological factors we need to single out, controlling for oil price and financial frictions in order better to elucidate the international TFP processes and their key drivers.

3. Empirical Model

In this section, we present a simple model that exposes the basic ideas and inspires our empirical work. It starts with the Cobb-Douglas production function with constant returns expressed in per worker terms:

, (1)

where y is the output per worker, A is the stock of knowledge, and k is the per worker capital stock. Using the natural logs, applying the first difference, and assuming a value of $\alpha = 1/3$ as suggested in the literature, we are able to isolate the growth of component A:[2]

(2)

Having identified the variable of interest, and aiming to examine how financial risk factor and oil price impact on TFP dynamics, we introduce the following equation:

, , (3)

is our proxy to measure the financial health of the banking sector and is computed as market-adjusted returns following Campbell et al. (1997) and Campbell and Limmack (1997). In more depth, the variable is the difference between banking sector stock returns and total stock market returns. is the price of West Texas Intermediate crude oil and the parameter is the long-run trend of TFP; finally, the captures the cyclical component based on the following structure:

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[2] Data explanation and sources are reported in the Data Appendix.

(4)

where (with) is a damping factor, is the frequency (measured in radians in the range , and are NID disturbances with zero means and common variance .

The parameters and in (3) are the time varying sensitivities to financial and oil risk factors, respectively. Both sensitivities are assumed to vary over time according to the following smoothing spline process:

, (5)

, (6)

Equations (3)-(6) form our state-space model that we estimated through the Kalman filter approach (Harvey, 1989). Starting values for the parameters, together with the appropriate lag of the variables *Δln(MAR)* and *Δln(OilPrice)* were obtained from the regression of the Solow residual (*Δln*(A_t)) with the two dependent variables adopting the general-to-specific approach of Hendry (1995).

As argued in De Nicolò and Lucchetta (2011), a huge negative *MAR* may be considered as an index of systemic risk, since the poor performance of the banking sector may be a signal of a financial disease that may result in credit supply cuts and/or increase in the cost of funds. We would therefore expect *MAR* to enter the TFP equation with a positive coefficient. Instead, as we discussed in the previous section, oil enters the production function, after which, increases in its price lead to increases in the cost of production, thereby reducing the TFP. Hence, sensitivity should exhibit a negative value within the TFP dynamics.

4. Empirical Results

In Table 1 we report estimates of the state-space system for the three countries over the period 1990-2014. On average, the explanatory power of the system is around 0.23 (R-squared) with robust statistical diagnostics.[3]

Table 1: TFP estimation results, 1990Q1-2014Q2.

		PEV		***Q***	***N***	***H***
US	0.001*	0.00	0.19	0.43	0.39	0.11
GER	0.001*	0.00	0.26	0.65	0.00	0.19
FRA	0.001*	0.00	0.23	0.21	0.09	0.07

Note: The Table reports model estimates of the equation over the period 1990-2014. *PEV* is the Prediction Error Variance; *N* is Jarque-Bera test; *H* is the Heteroskedasticity test; *Q* is the Box-Ljung Q-statistic. For *Q*, *N*, and *H* we report the corresponding *p*-value. The proper lag lengths in *Q* and the degree of freedom are selected by STAMP according to the number of observations. * denotes significance at 0.1 level.

The time-varying coefficients and for the US, Germany, and France are depicted in Figure 1 together with their 1.65 standard errors (SE) interval bars. For France and the US, the oil price coefficient exhibits the same decreasing pattern with positive to negative values, achieving statistical significance (when the 1.65 SEs bars do not include 0) from mid-2000 only for France, i.e. when the price reached high values; for the US, statistical significance is achieved only from 2010. Germany instead shows negative coefficients over the entire 1990-2014 period, thereby indicating an almost constant relationship between oil price movements and TFP dynamics. This result clearly suggests a German productivity significantly dependent upon oil trends, thereby confirming the findings of Carstensen et al. (2013), who proved that the oil price rise in 2007/2008 triggered a 0.8 percent reduction in German GDP in 2009. As preliminarily specified in their article, petroleum was the single most important energy source in Germany in 2010, accounting for about 34 percent of primary energy consumption and this "*figure has not changed significantly for the last 20 years*".

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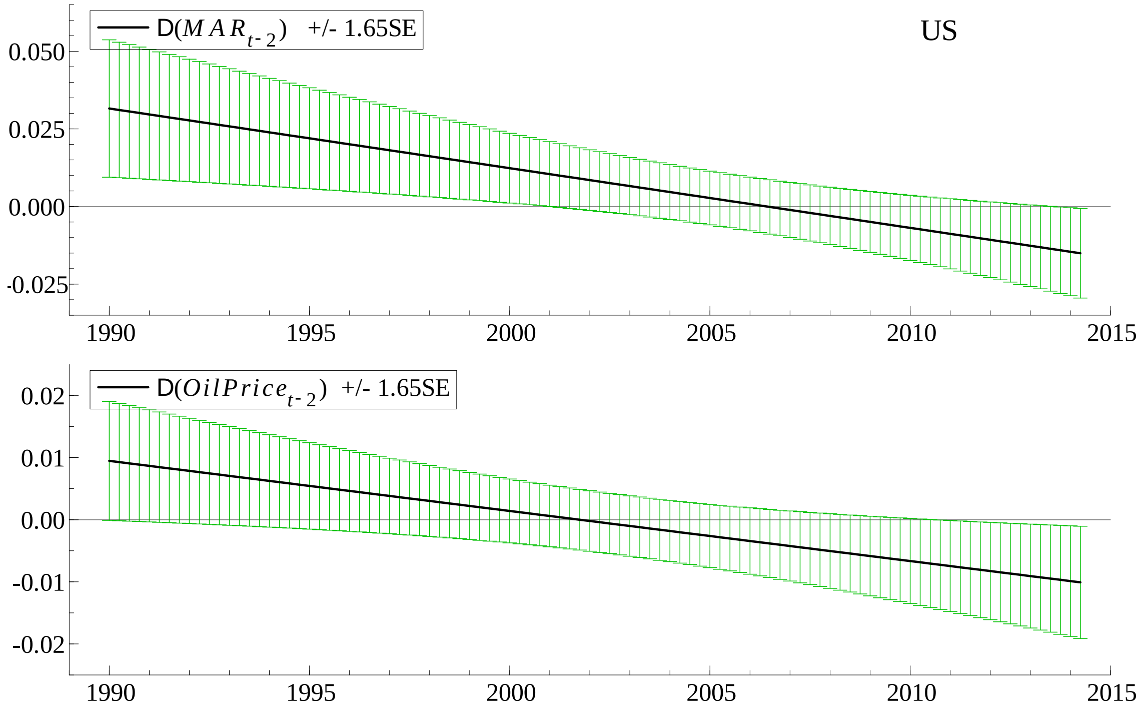
[3] The exception is the Normality test for the residuals of Germany equation. The auxiliary residuals analysis conducted with STAMP showed that the non-normality comes from a huge outlier in 2009. As showed by Koopman et al. (2007) this does not constitute a big problem and the model can be considered adequate if the other residual tests are satisfactory.

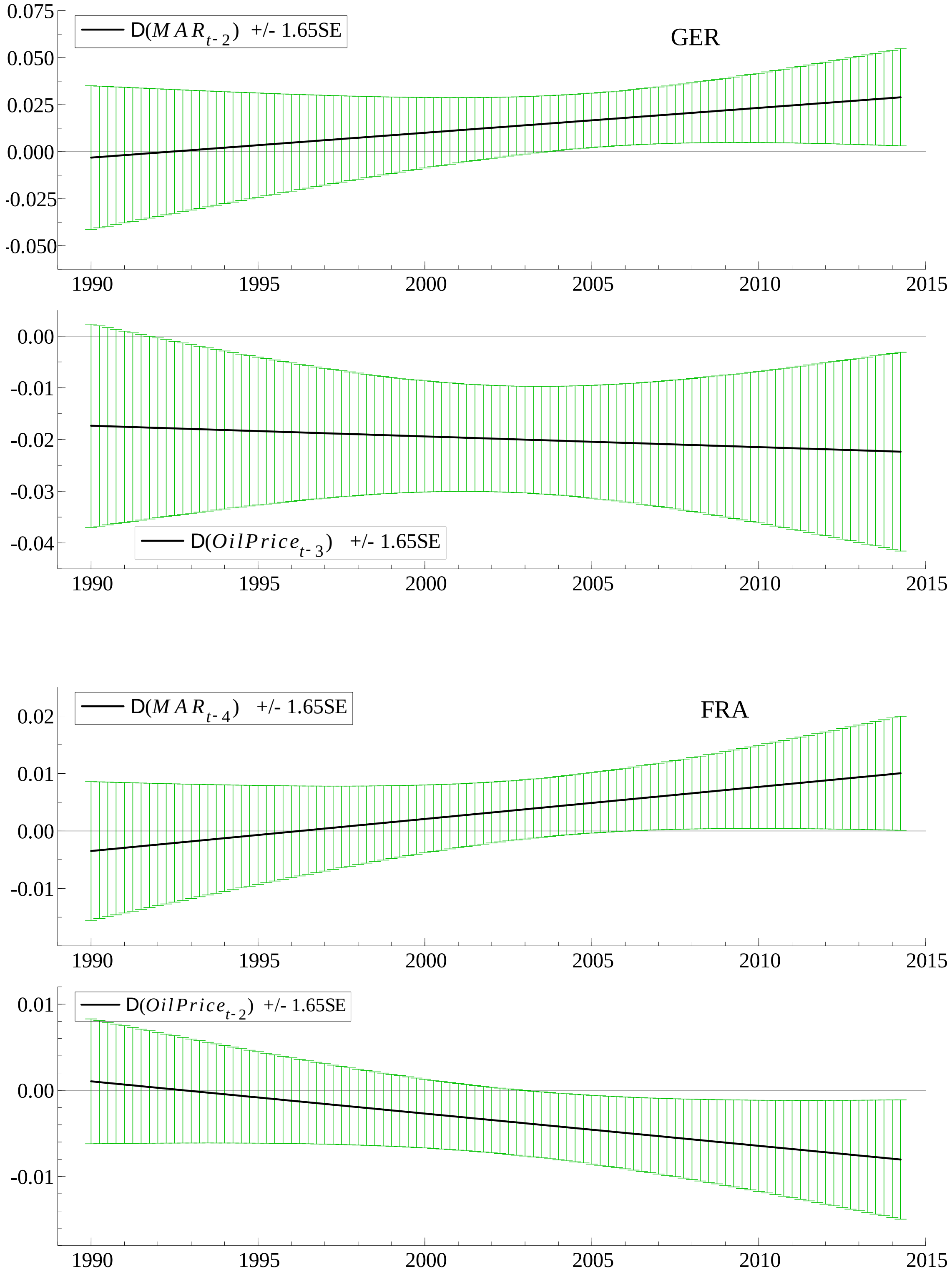
As a whole, we can conclude that the negative impact of oil price increases on real output is clearly confirmed for Germany and France, while such a relationship appears more uncertain for the US, because it operates only from 2010 (i.e. after the financial crisis). Based on the arguments of Blanchard and Gali (2007), a more flexible labour market, a more credible monetary policy and a smaller share of oil in the total production process are with all likelihood the key reasons explaining the lower (not significant) impact of oil price effect on US productivity.

The time-varying coefficient of *MAR* denotes a negative-to-positive tendency for France and Germany, only achieving statistical significance from the second half of the 2000s for both European countries. For the US, the tendency is instead from positive to negative, thus denoting a structural change starting by the 2000s, with sensitivity becoming negative but without statistical significance. Differences in the financial systems and technological leadership help to explain these results. As recently shown by Gambacorta et al. (2014), the financial structure in the US is strongly market-oriented, as proven by the ratio of bank credit to total private sector funding of 22 and 20 per cent over the sub-periods of 1991-2000 and 2001-2011, respectively. On the other hand, the same ratio calculated for the same sub-periods is 50 and 44 per cent, for France, and 53 and 56 per cent, for Germany (see Figure 2). Bank- and market-oriented financial systems have different impacts on productivity during a financial crisis. In principle, market-oriented systems "*may speed up the necessary deleveraging, thereby paving the way for a sustainable recovery*", while "*when banks are under strain, they are less able to help their clients through difficult times*". Gambacorta et al. (2014) provide evidence on this argument, as their results show that when recessions coincide with a financial crisis, bank-oriented countries exhibit an output cost of recession three times as severe (12.5% of GDP) as in those with a market-oriented financial structure (4.2% of GDP). Furthermore, Dell'Ariccia et al. (2008) find that banking crises had a stronger impact on industrial sectors dependent on external finance in terms of output growth. We can therefore plausibly conclude that US firms were hit less by the recent financial crisis and the losses in the banking system were not reflected in their productivity growth. US firms continued to innovate over time, notwithstanding the global recession, essentially because of more diversified financing channels, together with greater financial flexibility of firms.

A second tangential reason regards the US leadership in the technological innovation process. The US is home to the biggest and one of the most sophisticated and diversified industrial systems in the world (O'Sullivan et al., 2013), with firms operating in a competitive and global scenario (Schwab and Sala-i-Martin, 2014), with top global brands (i.e. in 2014, 25 out of 50 of the world's top brands are American) and contributing to approximately 41% of US private sector productivity gains since 1990 (Cummings et al., 2010). As largely discussed in the literature, a higher level of competitiveness produces stronger gains in productivity, as businesses must continuously introduce innovations to maintain and gain market share (see for example Aghion et al., 2005). And this competitiveness pressure, with its positive impacts on productivity, still remained, in spite of the financial crisis.

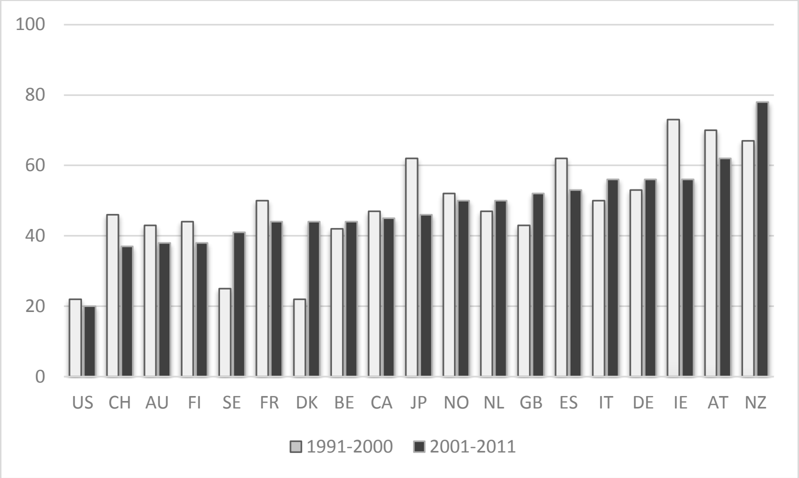
Figure 1: Time-varying estimates of and with 1.65 SE.





Note: The Figure reports the time-varying estimates of and (Equation (3)) also depicting the +/- 1.65 Standard Errors confidence bands.

Figure 2: Ratio of bank credit to total private sector funding (in percent)



Notes: US = United States; CH = Switzerland; AU = Australia; FI = Finland; SE = Sweden; FR = France; DK = Denmark; BE = Belgium; CA = Canada; JP = Japan; NO = Norway; NL = Netherlands; GB = United Kingdom; ES = Spain; IT = Italy; DE = Germany; IE = Ireland; AT = Austria; NZ = New Zealand. Sources: Gambacorta et al. (2014).

We finally inspected the evolution of the TFP spillover effects among US, France and Germany, focusing on the innovations of Equation (3) (i.e. the error terms). In this way we inspected the "pure" technological contagion, removing the influence that global factors (oil price and MAR) may exert in the forms discussed and explored in the previous sections.

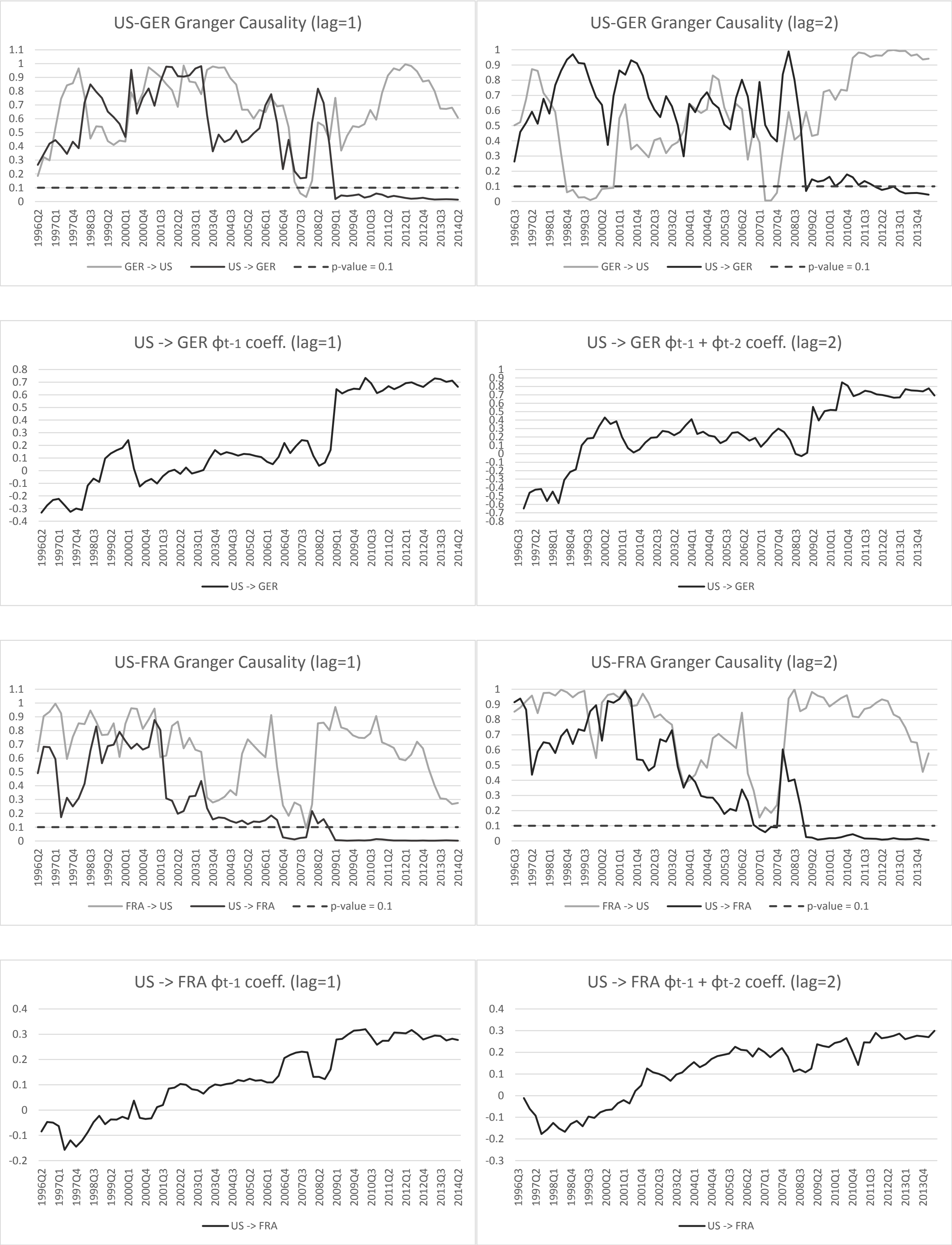
Computationally, we ran dynamic pairwise Granger causality tests among the TFP innovations of the three countries, using one and two lags in the regression according to the following equation

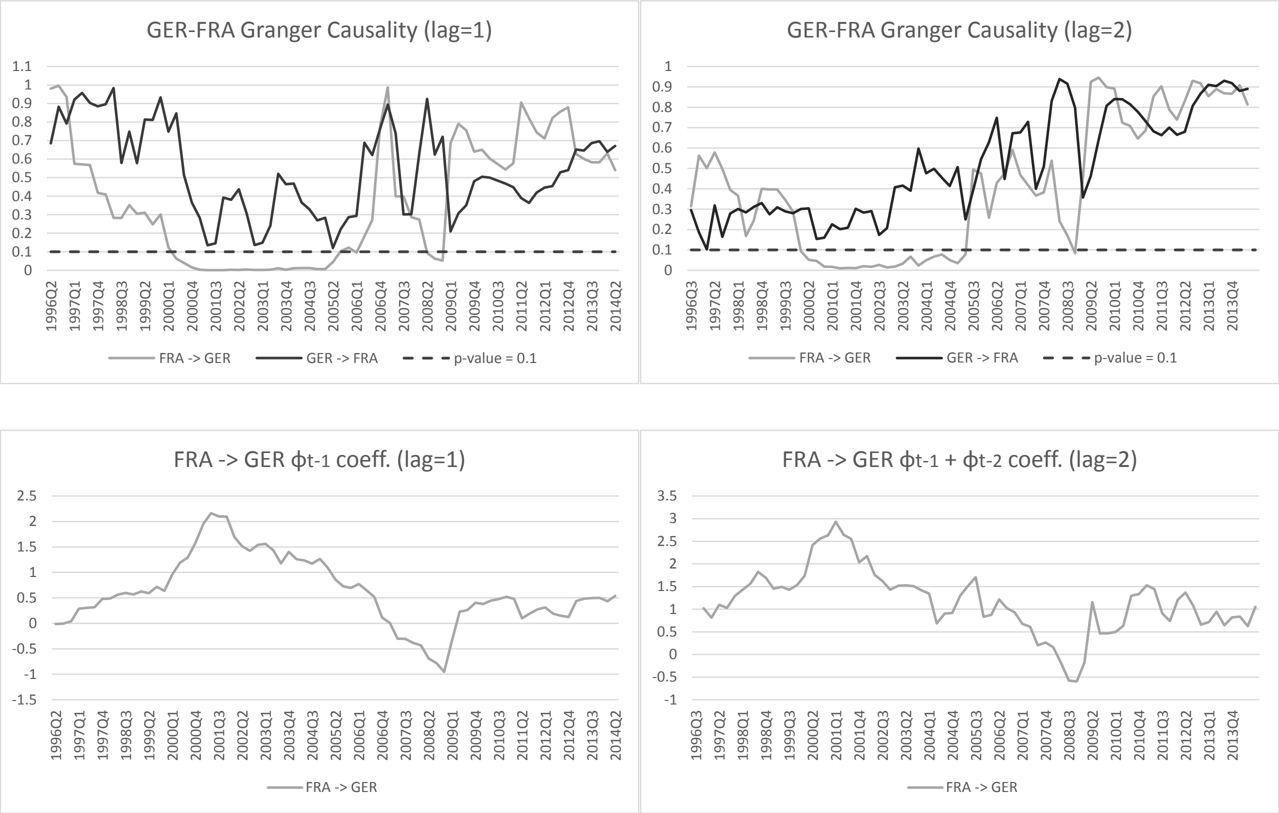
, (7)

where *m* was selected according to information criteria (i.e. AIC, SIC, HQ). Since the results are mixed (i.e. one or two lags), we opt to report the analysis with one and two lags. The test was run dynamically over a rolling window of 25 observations. The results are reported in Figure 3 together with the path of coefficients of the most statistically significant results. The main message coming from these paths is that the US was ahead of France and Germany after 2008, while France was ahead of Germany from the year 2000 to the mid-2000s. In both cases (US and France leaderships) the Granger coefficients are positive, thereby indicating that a rise/drop in US (French) TFP produces an increase/decrease in France and Germany (German) TFP. The following two points summarise our findings in more depth:

1) The results on France-Germany Granger causality, which indicate that France was only ahead of Germany over the period ranging from the year 2000 to the mid-2000s, are consistent with policy decisions taken by the German Government aimed at closing the gap between the West and East regions toward the end of the 1990s. Convergence between East and West Germany occurred rapidly in the early 1990s, but convergence stalled in the second half of the decade (Czarnitzki and Licht, 2006). Significant economic resources (€950 billion) were transferred from West to East Germany throughout the end of the 1990s and in the first half of the 2000s under the so-called *Solidarpakt I* programme. In that period, a lot of sources were devoted mainly to filling the gap between West and East regions, instead of incentivising the "frontier of innovation" at a national level. This logically explains why France achieved leadership in innovation in Europe during those years (i.e. 2000-2005). This is consistent with Cette et al.'s research results (2009) regarding TFP growth between the UK, France, and the US. The authors find that French TFP levels are higher and ahead of UK levels, and there are signs of convergence toward US levels in the periods between 2000-2006 in most sectors in France.
2) The results from the US-Germany and US-France Granger causality tests show that US pure TFP changes have caused German and French pure TFP dynamics from 2009. These are consistent with our previous analysis on the effect of oil price and financial risk on TFP. In Figure 1, we show that *MAR* produces a significant effect on France-Germany productivity from the second half of the 2000s. In recession periods, when both countries have difficulties in raising funds to invest in innovations, the only way to introduce technology improvements is to follow the country leader (i.e. the US), especially if the countries (France and Germany) have the know-how to imitate the technology leader. This is consistent with arguments reported in Eaton and Kortum (1999) and Barro and Sala-i-Martin (2004, chapter 8).

Figure 3: Dynamic Pairwise Granger Causality Tests and sign coefficients





Notes: the Figure reports the Granger causality test results according to the equation , where *m* is selected according to information criteria. The test was run dynamically over a rolling window of 25 observations. Results are robust to a different window size specification.

5. Concluding Remarks

Focusing on the US, France and Germany, in this paper we find new evidence on the relation between oil prices, financial frictions and TFP. Problems in the banking system impact on credit supply conditions; in turn, these problems negatively influence the fund sources available for innovative firms, thus amplifying the effects of real shocks to the economy. This result is particularly true for banking-based economies such as France and Germany. Conversely, the market-based nature of the US economy implies that the American firms are less sensitive to problems in the banking sector. Moreover, the global nature of US firms (Schwab and Sala-i-Martin, 2014) implies that they have to innovate continuously to maintain their leadership (Aghion et al., 2005). This is particularly true during recession periods and explains why the relation between financial frictions and TFP growth becomes negative during the second half of the 2000s. Oil price changes impact negatively on TFP growth, especially in periods of huge runs up, due to the increase in cost of production and the consequent reduction of internal sources available for investments. This is particularly true for France, whereas the effect is less clear for the US, because it is significant only after the financial crisis. Instead, for Germany we find a statistically and significant negative effect of oil price on TFP for the overall period. This result indicates substantial oil-oriented firm productivity in Germany, which is in line with the Carstensen et al. (2013) analysis.

Finally, exploring the technological spillover effects, we find that France was ahead of Germany during the first half of the 2000s, which is consistent with the political interventions taken by the German Government to reduce the gap between West and East regions (Czarnitzki and Licht, 2006) and the high observed French TFP growth with respect to the US and the UK in those years (Cette et al., 2009). Conversely, the banking-based nature of French-German economies explains why these countries seem to imitate the US technology pattern in correspondence of the years of financial crisis. In periods of recession, when both countries have difficulties in raising funds to innovate, the only way to introduce technological improvements is by following the country leader (i.e. the US).

Given the crucial role of TFP in driving long-run growth, these results have important policy implications. Hamilton (2009) has recently reminded that many observers "*suggested that the very rapid decline in short-term interest rates in 2008Q1 fanned the flames of commodity speculation, with negative real interest rates encouraging investments in physical commodities*". By explicitly targeting oil price dynamics, for example through commodity derivatives, Central banks would keep commodity speculation under control, with the aim to keep technological innovations immune from exogenous shocks. Likewise, as financial frictions have different impacts on productivity depending on the inner structure of the financial system, banking stability should be a major target also stimulating funding tools in R&D, being the impact on productivity substantial. Indeed, reducing technological gaps could also translate into a real growing convergence path within a more robust macroeconomic and financial system.

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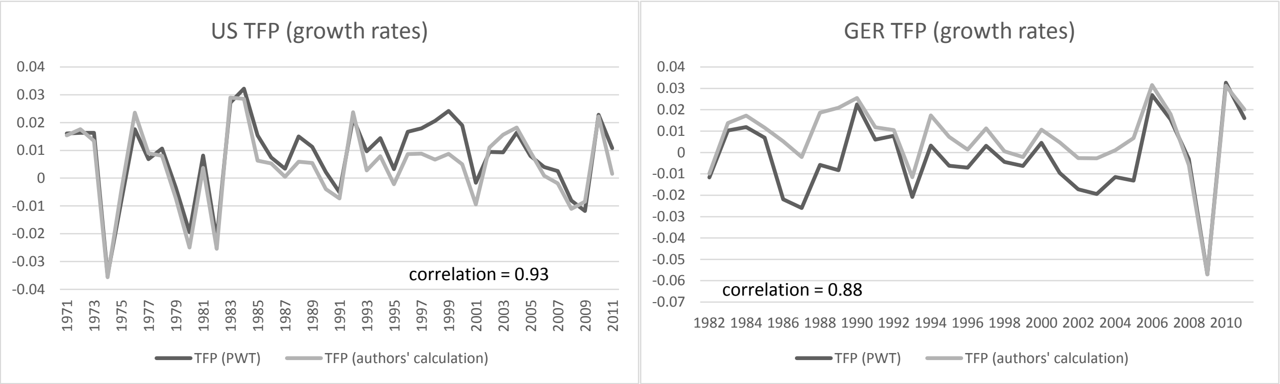
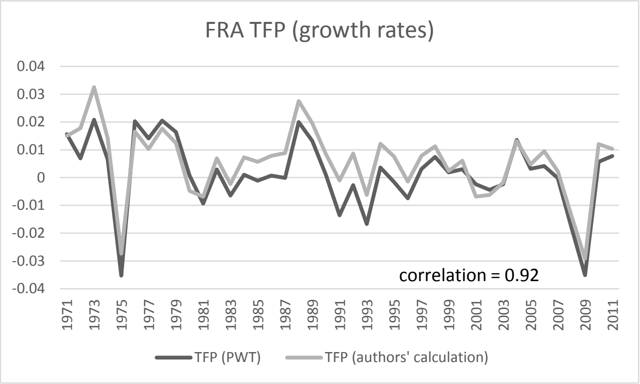
Data Appendix

Definitions and data source: 1990 Q1 – 2014 Q2		
Variable	Definition	Source
	Real GDP per worker: –.	Real GDP (seas. adj.), National Accounts basis (DATASTREAM). Total employment, National Accounts Basis (DATASTREAM).
	Real stock of knowledge obtained according to Eq. (2) in the text.	Authors' elaboration.
	Real capital stock (seas. adj.) of total economy	DATASTREAM.
	Market adjusted returns: . actual return of total stock market; actual return of banking sector.	Authors' elaboration on DATASTREAM data for total stock market and banking sector index.
	West Texas Intermediate oil price (US$/BBL).	Federal Reserve Economic Data (FRED)

To get an idea of whether the quarterly real TFP series has been calculated well, we compare the TFP series we obtained according to Eq.(2) in the text with the annual real TFP series of the Penn World Table. Quarterly series of TFP are transformed into annual series and plotted against annual TFP series from the Penn World Table. The below graph(Figure A) clearly shows that growth rates of the series are very similar with a very high correlation.

Figure A: Authors' calculation TFP vs the Penn World Table TFP




FRA TFP (growth rates)
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
correlation = 0.92
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
TFP (PWT)
TFP (authors' calculation)