Financial Markets and Innovation

By

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Abstract:

Because credit markets allocate capital efficiently, Schumpeter (1911) posits that banks can promote innovation, which is a vital component of economic growth. We examine a broad sample of 130 countries and document a strong positive association between credit market development and innovation, which we proxy using research and development. We also show that equity market development contributes to greater levels of R&D. Using the adoption of the Euro as a natural experiment, we conduct a series of difference-in-difference test to show that during the post-Euro period, those countries that adopted the Euro experience higher R&D than those that did not. To the extent that the adoption of the Euro provides an appropriate exogenous shock to the development of both credit and equity markets, these findings allow us to draw stronger causal inferences regarding the association between the development of financial markets and innovation.

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1. Introduction

Among the many factors that have been shown to drive economic growth in the macroeconomic literature, technological innovation has received a great deal of attention. Solow (1956) models long-run economic growth as a function of improvements in productivity, and in equilibrium, permanent growth is only obtainable in the presence of technological change. Romer (1990) contends that economic growth is endogenous and a production function made up of the marginal product of capital, as well as capital stock, generates higher levels of economic output. Therefore, both technological innovation and human capital accumulation contribute to growth. Of course, capital stock is driven by the level of investment, and Pagano (1993) shows that financial markets provide an important link between gross savings and gross investment. When markets function properly, a greater proportion of gross savings flows into higher levels of investment. In other words, markets allocate the savings of individuals to the most innovative firms, which leads to higher steady-state economic growth rates.

The primary objective of this study is to revisit whether credit markets contribute to country-level innovation. Schumpeter (1911) proposes that the banking system promotes greater innovation through the mobilization of savings, managing of risk, monitoring of agency costs, and evaluation of projects, which in turn, leads to higher economic growth. In contrast, Hsu, Tian, and Xu (2014) contend that, relative to equity markets, credit markets are less likely to affect innovation for two reasons: first, the intermediation process of banks does not provide a reliable price signal about which firms, or which projects, will be profitable. Without an accurate price signal, capital will not always be efficiently allocated. Second, the most innovative firms might not generate the consistent cash flows necessary to service high debt levels. Therefore, whether or not credit markets generate innovation becomes an empirical question.

Consistent with Schumpeter (1911), King and Levine (1993) and Levine and Zervos (1998) show that credit market development is associated with higher rates of economic growth. However, Hsu, Tian, and Xu (2014) examine cross-country data and provide evidence that while equity market development is associated with innovation at the country-level, credit market development is not. Remarkably similar results are found in Bravo-Biasca (2007). Our research is most closely related to Bravo-Biosca (2007) and Hsu, Tian, and Xu (2014). However, these two existing studies use a sample of approximately 30 countries and examine patenting activity as the primary measure of innovation. In our analysis, we examine a sample of 130 countries and proxy innovation using two different measures: (1) the total amount of R&D expenditures in a particular country during a particular year and (2) the number of researchers in R&D in each country. Admittedly, Hsu, Tian, and Xu (2014) also use R&D expenditures as an alternative measure of innovation; however, the data used in their study only consist of expenditures for a subset of publicly traded firms in each country. The R&D expenditures used in our study capture the total gross domestic (capital and current) expenditures in R&D in four broad areas that include "Business Enterprises", "Higher Education", the "Private Sector", and the "Non-Profit Sector". Given the differences in sample size and the coverage in R&D expenditures, new tests regarding the association between credit market development and innovation seem to be warranted.

Both univariate and multivariate results show that, in a particular country, the credit provided by banks (as a percent of GDP) directly affects the amount of R&D expenditures. These results are robust to controls for various macroeconomic variables such as GDP per capita, net exports, gross savings, government spending, and capital formation. In economic terms, a one standard deviation increase in bank credit is associated with a 4% increase R&D expenditures. Similar results are found when we examine credit provided by the entire finance sector (instead of just banks) as well as credit provided directly to the private sector. To the extent that our measure of R&D expenditures properly captures innovation, our findings run counter to those in Bravo-Biosca (2007) and Hsu, Tian, and Xu (2014), and suggest that credit markets are an important determinant in the level of innovation in our sample of countries. We document similar results when we examine the number of R&D researchers instead of R&D expenditures in a particular country.

Since credit and equity markets compete for capital investments, we also examine the contribution of equity market development to innovation levels. In particular, we use three proxies for equity market development including the market capitalization of all publicly traded firms (as a percent of GDP), the trading volume (as a percent of GDP) on a particular country's stock exchanges, and the share turnover – or the ratio of trading volume to market capitalization. Our multivariate results show that equity market development is positively associated with R&D expenditures and the number of researchers in R&D. These findings support the earlier empirical work on the topic (Bravo-Biosca (2007) and Hsu, Tian, and Xu (2014)) and highlight the complementary effects of credit and capital markets on innovation.

Finding a positive association between both credit market and equity market development and innovation is not tantamount to determining that the development of these financial markets causes greater levels of innovation. Our study also contributes to the existing literature by attempting to provide a causal link between financial market development and innovation. We use the adoption of the Euro as a shock to economic development and conduct a series of difference-in-difference tests for participating and non-participating countries. Prior research suggests that the adoption of the Euro improved the level of financial development – both credit market and equity market development – of Eurozone countries vis-à-vis non-Eurozone countries (Galati and

Tsatsaronis (2003), Bartram, Taylor, and Wang (2007), and Masten, Coricelli, and Masten (2008)). We argue that the adoption of Euro is exogenous to the level of innovation in European countries. We find that Eurozone countries, relative to non-Eurozone countries, experience both higher R&D expenditures as well as an increase in the number of R&D researchers during the period immediately following the adoption of the Euro. Combined with our previous findings, these latter results seem to indicate that causation seems to flow from credit/equity market development to innovation.

The results in this study contribute to the existing literature in three important ways. First, we provide general evidence of Schumpeter's (1911) proposal that financial markets (credit and equity) contribute to the level of innovation in a particular country, which may lead to higher rates of economic growth. Second, using a broad cross-section of countries and various measures of innovation, we find that credit markets are an essential element in determining innovation levels, which is contrary to the findings of Bravo-Biosca (2007) and Hsu, Tian, and Xu (2014). Third, our results speak to the direction of causation using the adoption of the Euro as a natural experiment.

The rest of this paper follows. Section 2 provides a brief review of the literature. Section 3 describes the data. In Section 4, we report the results from our empirical tests. Section 5 offers some concluding remarks.

2. Literature Review

In this section, we describe the literature that relates to our research question. We first highlight the existing research on the link between finance and economic growth. Second, we discuss several studies that describe the association between financial markets and innovation.

The relation between financial markets and growth has been debated extensively. Schumpeter (1911) was the first to contend that credit markets leads to economic growth. He argues that banks lead to innovation and subsequently economic growth because credit markets allow capital and resources to be allocated efficiently. This in turn reduces the risk of loss caused by adverse selection, moral hazard, and transaction costs. In contrast, Lucas (1988) argues that economists "badly over-stress" the role of financial markets in explaining economic growth. Empirically, however, several studies show evidence of a direct association between the development of financial markets and economic growth. For instance, King and Levine (1993) show that, in the 80 countries sampled, financial development is strongly related to economic growth rates and the growth of capital accumulation. Similarly, Levine and Zervos (1998) examine about 40 countries and find that well-functioning credit markets and liquid equity markets both lead to higher long-run economic growth rates, greater savings rates, and higher capital formation rates.

Finding a positive relationship between financial development and economic growth does not imply that well-functioning financial markets cause higher growth rates. In fact, Robinson (1952) argues that economies with good growth opportunities develop financial markets to provide funding for those growth opportunities. Said differently, instead of financial development causing higher levels of economic growth, causation might flow the other way (economic growth might cause the development of financial markets).

One way that researchers have tried to disentangle the endogeneity between finance and economic growth is to examine more carefully some of the underlying mechanisms that lead to economic growth. Schumpeter's (1911) hypothesis that finance will lead to economic growth is based on the mechanism of innovation. Other studies have also documented that innovation is one of the main drivers of economic development and has been studied from many vantage points. For example, Abramovitz (1956) demonstrates that economic growth is primarily driven by increases in productivity, which is a form of innovation.

In another important stream of research, Cohen and Levinthal (1990) carried the ideas of knowledge absorption to the firm level, which they identify as research and development (R&D). Although firms innovate in a variety of ways, much of the measurable innovation can be attributed to R&D. In that light, Griffith, Redding, and Van Reenen (2004) aggregate R&D to the country level. They find that research and development stimulates innovation and growth directly and conclude that U.S. based studies may underestimate the impact of R&D. Given the use of R&D expenditures as a measure of innovation in our study, these preceding studies provide an important motivation for our tests.

In other studies, Eaton and Kortum (1999) model the diffusion of innovation across countries and highlight the fact that the research effort is determined by how much can be earned by innovating at home and abroad. They examine the cross-country differences in patent protections and find that international research is only two-thirds as valuable as domestic research. Fagerberg, Srholec, and Verspagen (2010) provide a comprehensive overview of the link between innovation and economic development.[4]

Several papers have extended research on the topic of finance and economic growth by exploring how external finance and financial markets relate to innovation and thus economic development. Rajan and Zingales (1998) examine the costs of external financing and find that industrial sectors that need more external financing develop disproportionately faster in countries

[4] In other related studies, Ferreira, Manso, and Silva (2014) show that it is optimal to go public when exploiting existing ideas and optimal to go private when exploring new ideas. Nanda and Rhodes-Kropf (2011) find that capital allocation in “hot” markets leads to increased innovation. Hall and Lerner (2010) find that knowledge assets that R&D investments create are usually intangible and hard to disentangle from human capital.

with more developed financial markets. King and Levine (1993b) construct an endogenous growth model where financial markets aid the innovation process by allowing participants to diversify risks. Specifically, they find that better financial systems improve the probability of successful innovation and thereby accelerate economic growth. Similarly, Bravo-Biosca (2007) finds that both equity and credit markets increase innovation but that equity markets are generally associated with more radical innovation than credit markets. He finds that industries that are more dependent on external finance innovate more in countries with higher financial development. Specifically, he decomposes the effect of banks and stock markets on patents and finds that both significantly increase patenting activity. He also highlights some differences between equity and credit markets. Stock markets are associated with higher quality patents while banks are not and more volatile industries are more innovative in countries with more developed stock markets but not credit markets. Hsu, Tian, Xu (2014) examines how financial market development affects technological innovation. Similar to the Bravo-Biosca (2007), they examine approximately countries and, using the same empirical specifications, they find that more high-tech industries exhibit higher levels of innovation in countries with better developed markets. Given the similarities between the studies, not surprisingly, Hsu, Tian, and Xu (2014) find differences in equity markets compared to credit markets with most of the innovation driven by equity markets.

3. Data Description

The data used throughout this study are obtained from the World Bank. We obtain two samples. The first sample contains data from 130 countries with reported credit market indicators. In particular, we gather data on the amount of domestic credit offered by banks as a percent of GDP (*Bank Credit*), the amount of domestic credit offered by the entire financial sector as a percent of GDP (*Finance Credit*), and the amount of credit offered to the private sector as a percent of

GDP (*Private Credit*). The second sample contains data from 82 countries that report equity market indicators. The three indicators are *MCAP*, *Volume*, and *Turnover*. *MCAP* is the total market capitalization of all domestic companies listed on a particular country's stock exchanges. *Volume* is the amount of dollar volume for all foreign and domestic stocks that trade on a country's exchange. *Turnover* is the amount of trading volume scaled by market capitalization.

The main variables of interest include *R&D/GDP* and # *of Researchers*. *R&D/GDP* is the amount of research and development expenditures in a particular country scaled by GDP. The # *of Researchers* is the total number of researchers in R&D per million population. These two measures of innovation will be used throughout the analysis. We note, however, that these variables became available in 1996 from the World Bank. Therefore, the sample time period extends from 1996 to 2015. The first sample contains approximately 1,400 country-year observations, while the second sample contains about 1,000 country-year observations.

We also gather several control variables that will be used in our multivariate tests. *GDP/Capita* is the amount of GDP per capita. *NETEX* is the difference between total exports and total imports. *Savings/GDP* is the amount of gross savings scaled by GDP. *Gov't Spending* is the amount of national expenditures in U.S. dollars. *Cap. Formation* is the amount of capital formation in U.S. dollars.

Table 1 reports summary statistics for both samples. Panel A shows the descriptive statistics for the 130 countries that report credit market indicators. We show that the average country in our sample spends about 1% of GDP on R&D and has nearly 2,000 (per million population) R&D researchers. Relative to GDP, the average country also offers credit from banks, the financial sector, and tothe private sector in the amounts of 34%, 49%, and 36%, respectively. The average country in our sample has GDP per capita of about $16,500. The average country has net exports of about $2 million, government spending of $623 million, and capital formation of about $153 million. We also find that the average country has about 22% of GDP made up of gross savings.

Panel B of Table 1 describes the sample of 82 countries that report equity market indicators. We note that the statistics for *R&D/GDP* and *# of Researchers* are very similar to the corresponding statistics in Panel A. For instance, the average country in this sample spends 1.20% of GDP on R&D and has roughly 2,283 (per million population) R&D researchers. We also note that the average country has *MCAP/GDP* of about 69%, *VOLUME/GDP* of nearly 44%, and *Turnover* of approximately 60%.

Table 2 reports the Pearson correlation coefficients between the variables used in the analysis. Panel A shows the correlation matrix for the sample of 130 countries that report credit market indicators. A few results are noteworthy. First, in column [1], we find that *R&D/GDP* is heavily correlated with the *# of Researchers* – which is to be expected. In fact, the correlation coefficient between these two variables is 0.9061, which is significant at the 0.01 level. The first column also shows that *R&D/GDP* is positively related to *Bank Credit*, *Finance Credit*, and *Private Credit*. The correlation coefficients, which are 0.5348, 0.6284, and 0.5901, are both statistically and economically significant. Similar results are found in column [2] as the *# of Researchers* is positively associated with the three credit market indicators. The other correlations are reported in the remainder of the table.

Panel B of Table 2 shows the correlation coefficients for the sample of 82 countries that report equity market indicators. Column [1] shows that *R&D/GDP* has strong, positive correlations with all three equity market indicators, 0.1141 (*MCAP/GDP*), 0.2597 (*Volume/GDP*), and 0.2287 (*Turnover*), respectively. Admittedly, the correlations are lower than the corresponding correlations in Panel A where we analyze the correlations between innovation and credit market indicators. Column [2] presents the correlations between the *# of Researchers* and the equity market indicators. Again, we find that the correlation coefficients are positive and significant. The correlation in Tables 2 provide an initial glance at our hypothesis and seem to highlight the important role that both credit markets and equity markets play in innovation at the country level.

4. Empirical Results

In this section, we present the results from our empirical tests. We begin by analyzing whether or not credit markets affect innovation in a particular country. Next, we examine the relation between the development of these markets and innovation. Last, we perform a series of difference-in-difference tests between eleven European countries that adopted the Euro beginning in 1999 and those that did not. We contend that the adoption of the Euro provides an exogenous shock to both credit and equity markets in those countries (e.g. Galati and Tsatsaronis, 2003; Bartram, Taylor, and Wang, 2007; Bekaert, et al., 2013), which allows us to make stronger causal inferences.

4.1. Credit Markets and Innovation

In this subsection, we examine whether or not credit markets are directly linked to innovation. We begin by estimating a simple linear model of the following form:

$$\begin{aligned} \ln(R\&D/GDP)_{i,t} \; or \ln(\#\; of\; Researchers)_{i,t} \\ = \beta_0 + \beta_1 Credit^{j}_{i,t} + \beta_2\, GDP/Capita_{i,t} + \beta_3 NETEX_{i,t} + \beta_4 Savings/GDP_{i,t} \quad (1) \\ + \beta_5 Gov't\; Spending_{i,t} + \beta_6 Cap.Formation_{i,t} + \varepsilon_{i,t}, \end{aligned}$$

where the dependent variable is the natural log of the ratio of R&D expenditures to GDP for country *i* in year *t*, or the natural log of the number of R&D researchers per million population. We measure the amount of credit available for consumers in a particular country in one of three ways: First, the natural log of the domestic credit offered by banks (*Bank Credit*). Second, the natural log of the domestic credit offered by the financial sector (*Fin. Credit*). Third, the natural log of the domestic credit offered to the private (*Private Credit*). Because these variables are highly correlated, we introduce them individually into equation (1). We control for total country output, exports and imports, savings, government spending, capital formation, and year fixed effects.

Table 3 reports the coefficient estimates from equation (1) with the natural log of the ratio of R&D expenditures to GDP as the dependent variable. We report *t*-statistics in parentheses obtained from robust standard errors. In columns [1] and [2] of Table 3, we examine the relation between domestic credit offered by banks and R&D expenditures. We find a significant positive relation between the amount of credit offered by banks and a country's spending on R&D. In a simple regression, controlling for only time series variation in *R&D/GDP*, we find that a percent increase in the amount of credit offered by banks is associated with a 0.5686% increase in R&D expenditures. After controlling for observable factors, we continue to find a significant positive relation between bank lending and innovation. In economic terms, the results in column (2) show that a percent increase in credit offered by banks is associated with a 0.1220% increase in R&D expenditures. Alternatively, a one standard deviation increase in credit offered by banks is associated with a 4.1199% increase in R&D spending.

In columns [3] and [4] of Table 3, we analyze the relation between domestic credit offered by the financial sector and innovation. We find a strong positive association between credit offered by the financial sector and the country's R&D expenditures. In a simple regression controlling for only year trends, we find that a percent increase in credit offered by the finance sector is associated with a 0.6156% increase in a country's spending on R&D. After controlling for other factors, we find that a percent increase in the domestic credit offered by the finance sector is associated with a 0.2053% increase in R&D expenditures. These result are significant at the 0.01 level. Therefore, in countries where credit lending from the finance sector is higher, technological innovation, as measured by R&D expenditures, is higher.

The final two columns of Table 3 report the results from equation (1), where the amount of credit offered to the private sector is the variable of interest. Similar to before, we find that more credit offered to the private sector increases R&D. Controlling for time trends, the results show that a percent increase in domestic credit offered to the private sector is associated with a 0.5759% increase in R&D expenditures. Other factors held constant, we find that a one percent increase in credit offered to the private sector increases spending on R&D by 0.1035%. These findings seem to indicate that better access to credit markets increases innovation at the country level and supports the arguments of Schumpeter (1911).

Since R&D expenditures may be an incomplete proxy of a country's level of innovation, we also examine the relation between credit markets and the number of R&D researchers per capita. We re-estimate equation (1) replacing the dependent variable with the natural log of the number of R&D researchers per million people in country *i* in year *t*. The results in columns [1] and [2] of Table 4, show a positive relation between credit offered by banks and the number of R&D researchers in a particular country. The results are both statistically significant at the 0.01 level and economically meaningful. For instance, holding constant the time series variation in R&D, we find that a one percent increase in domestic credit offered by banks is associated with a 1.1647% increase in the number of R&D researchers in a particular country. However, holding other factors constant, the result show that a percent increase in domestic bank credit is associated with only a 0.2280% increase in the number of R&D researchers. While the result is diminished, it remains economically significant.

In columns [3] and [4] of Table 4, we examine the relation between domestic credit offered by the entire financial sector and the number of R&D researchers in a country. In a simple model controlling for only year fixed effects, we find that a one percent increase in the amount of credit offered by the financial sector is associated with a 1.1589% increase in the number of R&D researchers in a particular country. Even after controlling for other factors that influence R&D, we continue to find that a percent increase in credit offered by the financial sector increases the number of R&D researchers in a country by 0.3019%. These results are significant at the 0.01 level and suggest that better access to financial credit markets increases innovation.

The results in the final two columns of Table 4 show a significant positive relation between the amount of credit offered to the private and the number of R&D researchers in a country. Depending on the regression model, a one percent increase in the amount of credit offered to the private is associated with between a 0.2035% and 1.1483% increase in the number of R&D researchers in a particular country. While these results are both significant at the 0.01 level, they differ substantially in terms of economic magnitude. Nevertheless, it appears that more credit offered to the private increases a country's level of innovation.

The results in Tables 3 and 4 suggest that better access to credit markets is directly related to a country's technological innovation. These findings run contrary to the those in Hsu, Tian, and Xu (2014) who use a sample of countries that only one fourth the size of the sample used in this study. To the extent that innovation is a major force in economic growth (e.g. Rosenberg, 2004), our results might indicate that accessible credit markets improve economic output.

4.2. Equity Markets and Innovation

In this subsection, we follow Hsu, Tian, and Xu (2014) and analyze whether or not liquid stock markets affect the level of R&D in a particular country. To test this research question, we estimate the following regression equation:

$$\ln(R\&D/GDP)_{i,t} \text{ or } \ln(\#\ of\ Researchers)_{i,t}$$
$$= \beta_0 + \beta_1 Equity^j_{i,t} + \beta_2\, GDP/Capita_{i,t} + \beta_3 NETEX_{i,t} + \beta_4 Savings/GDP_{i,t} \quad (2)$$
$$+ \beta_5 Gov't\ Spending_{i,t} + \beta_6 Cap.Formation_{i,t} + \varepsilon_{i,t}.$$

Similar to above, the dependent variable is the natural log of the ratio of R&D expenditures to GDP for country i in year t, or the natural log of the number of R&D researchers per million population. The independent variable of interest, $Equity^j_{i,t}$, is set to one of three variables. First, the natural log of the ratio of market capitalization for all publicly traded stocks (both domestic and foreign) to GDP. Second, the natural log of the dollar volume of all shares traded divided by GDP. Third, the natural log of all shares traded on domestic markets scaled by market capitalization. Again, we control for a country's total gross output, exports and imports, savings, government spending, and capital formation. We also include year fixed effect and report *t*-statistics obtained from robust standard errors.

In Table 5, we report the results of estimating equation (2) inserting R&D expenditures as the dependent variable. Column [1] shows a significant positive association between a country's total market capitalization and spending on R&D. Specifically, holding constant year trends, a percent increase in market capitalization is associated with a 0.3212% increase in R&D expenditures. In column [2], we report the results from the full model specification, and we fail to find a significant coefficient on the ratio of market capitalization to GDP. This result suggests that after holding constant various economic factors, we do not find that a country's stock market capitalization affects R&D spending in a meaningful way.

In columns [3] and [4] of Table 5, we examine the relation between a country's stock trading volume and innovation. Holding constant time series variation in R&D spending, we find that a percent increase in the ratio of stock trading volume to GDP is associated with a 0.2459% increase in R&D expenditures. After holding constant other factors, we show that a one percent increase in trading volume to GDP increases R&D spending by 0.1059%. Our results seem to indicate that a more active stock market increases innovation, in the form of increased R&D.

The final two columns of Table 5 show that stock turnover is positively related with R&D expenditures. Depending on the model specification, we find that a one percent increase in stock turnover increases spending on R&D between 0.1678% and 0.3076%. These results are significant at the 0.01 level and economically impactful. Thus, a more liquid stock market is directly related to technological innovation in a particular country. These findings might be explained by theory in Levine (1991) and Bencivenga, Smith, and Starr (1995) that suggests that liquidity in stock markets lowers the disincentives associated with investing in capital projects that have longer duration. To the extent that R&D fits the category of a longer duration investment project, our results can be explained by the preceding theory on the topic.

To further analyze the relation between equity markets and innovation, we re-estimate equation (2) inserting the natural log of the number of R&D researchers as the dependent variable. The results of this analysis are reported in Table 6. In column [1], we find a significant positive correlation between a country's total stock market capitalization and the number of R&D researchers. For instance, controlling for year fixed effects, we find that a one percent increase in market capitalization to GDP increases the number of R&D researchers in a country by 0.3187%. We note, however, that this result disappears after controlling for known determinants of R&D.

Therefore, we provide limited evidence that the level of stock market capitalization in a country is directly linked to innovation.

In columns [3] and [4] of Table 6, we show a significant positive relation between the ratio of stock trading volume to GDP and the number of R&D researchers in a country. In the restricted regression model, controlling for only year fixed effects, we find that a percent increase in stock trading volume to GDP is associated with a 0.2459% increase in the number of R&D researchers. In the full specification model, we find that a one percent increase in trading volume to GDP is correlated with a 0.0562% increase in the number of R&D researchers. While the latter result is substantially smaller, it remains significant at the 0.01 level and economically meaningful. For instance, a one standard deviation increase in trading volume to GDP is associated with a 4.5601% increase in the number of R&D researchers, other factors held constant.

In the final two columns of Table 6, we report the results from our last set of tests in this subsection. We examine the relation between a country's equity market turnover and the amount of individuals researching in R&D fields. Depending on the model specification, we find that a one percent increase in a country's stock market turnover is associated with between a 0.1080% and 0.2398% increase in the number of R&D researchers. Therefore, stock market liquidity in a country appears to be directly related to technological innovation, as measured by R&D expenditures and the number of researchers in R&D related projects.

Collectively, the results in Tables 5 and 6 seem to suggest that, in addition to credit markets, stock markets affect the level of innovation in a given country. Companies in countries with more liquid and active stock markets appear to expend more time and resources on R&D.

4.3. R&D and the Adoption of the Euro

To this point in the analysis, we have shown positive linear relations between credit and stock markets and technological innovation. In this subsection, we attempt to draw more causal inferences by conducting a difference-in-difference analysis surrounding the adoption of the euro. Beginning in 1999, eleven European countries adopted a single currency, the euro, which had significant financial market implications. For instance, Galati and Tsatsaronis (2003) show that the euro improved liquidity in the interbank deposit market, corporate bond market, and equity market. The authors find that European companies were able to raise funds at an 'unprecedented' rate after the adoption of the euro. Similar results are found in (Bartram, Taylor and Wang (2007) and Masten, Coricelli, and Masten (2008)).

We use the introduction of the euro as a positive exogenous shock to both credit and equity markets. We then analyze the level of technological innovation in European countries that adopted the euro against those that remained outside of the union around the implementation period. The regression model takes the following form:

$$\begin{aligned}\ln(R\&D/GDP)_{i,t} \; or \ln(\# \; of \; Researchers)_{i,t} \\ &= \beta_0 + \beta_1 Euro_i + \beta_2 Post_t + \beta_3 Euro_i \times Post_t + \beta_4 \, GDP/Capita_{i,t} \\ &+ \beta_5 NETEX_{i,t} + \beta_6 Savings/GDP_{i,t} + \beta_7 Gov't \; Spending_{i,t} \\ &+ \beta_8 Cap.Formation_{i,t} + \varepsilon_{i,t} \,,\end{aligned} \tag{3}$$

where the dependent variable is set to either the natural log of the ratio of R&D expenditures to GDP or the natural log of the number of R&D researchers per million population. *Euro* is a categorical variable equal to one if the country adopted the euro beginning in 1999, and zero for European countries that did not adopt the euro. *Post* is an indicator variable capturing the period from 1999 to the end of the sample time period. The interaction term is the difference-in-difference estimator. Once again, we include as control variables a country's total gross output, exports and imports, savings, government spending, and capital formation. We report *t*-statistics obtained from robust standard errors. We report the results from this analysis in Table 7.

In columns [1] and [2] of Table 7, we examine R&D expenditures around the introduction of the euro. For countries that adopted the euro post-1999, relative to those that did not, we find an increase in R&D expenditures of 24.60% after the implementation period. Holding other factors constant, we find that this increases to 39.86%, which is significant at the 0.01 level. In columns [3] and [4] of Table 7, we examine the change in the number of R&D researchers in European countries that adopted the euro post-1999, relative to those that did not. Depending on the model specification, we find that the number of R&D researchers increases between 36.61% and 38.62% more for European countries that adopted the euro post-1999, relative to those that did not.

To the extent that the adoption of the euro acts as a positive exogenous shock to the credit and capital markets in the participating countries, our results suggest that financial market development causes an increase in innovation.

5. Concluding Remarks

Much of the more recent theoretical literature in macroeconomics highlights the role that technological innovation plays in explaining long-run and permanent economic growth. Building upon the Solow (1956) model, Romer (1990) introduced endogenous growth theory and showed that, in its simplest form, the production function that underlies economic output is driven by innovation and capital. Well-functioning financial markets play an important role in economic growth, given that gross savings contribute to capital investment, which drives both innovation and capital accumulation. In fact, Pagano (1993) shows that steady-state growth rates are positively associated with the development of financial markets. Schumpeter (1911) posits that among the many benefits associated with a proper banking system, the efficient allocation of capital is the most important, as it can spur the level of innovation in a particular country. To the contrary, Hsu, Tian, and Xu (2014) suggest that, relative to equity markets, credit markets might not promote innovation as the intermediation process of banks does not provide credible price signals about which firms are most innovative. Therefore, whether or not credit markets promote innovation becomes an empirical question, which we seek to answer in this study.

Examining a large cross-section of countries, both univariate and multivariate tests show a strong positive association between the credit offered by banks (and other financial institutions) and R&D, which we use to proxy innovation. The results are not only statistically significant, but the estimates are also economically meaningful. For instance, after controlling for a number of macroeconomic factors, a one standard deviation increase in the amount of credit offered by banks is associated with a 4% increase in R&D expenditures. These results are robust to other measures of innovation as well as other measures of credit market development. We also find that liquid equity markets promote innovation. These latter findings support the theory in Levine (1991) and Bencivenga, Smith and Starr (1995) that suggests that liquid stock markets reduce the disincentives for investors to provide capital to innovative firms that fund projects with longer durations. Combined, we provide evidence that both credit markets and equity markets are important in promoting the level of innovation across countries.

In an attempt to draw more causal inferences, we use the adoption of the Euro as a natural experiment. Prior research (Galati and Tsatsaronis (2003), Bartram, Taylor, and Wang (2007), and Masten, Coricelli, and Masten (2008)) shows that the implementation of the Euro leads to greater financial development in both credit markets and equity markets for participating countries. Using this event as an arguably exogenous shock to financial market development, our difference-in-difference tests show that, relative to non-Eurozone countries, those countries that adopted the

Euro experience greater levels of innovation during the post-adoption period. Thus, our paper offers new insights into the real effects of financial market development on innovation.

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Table 1 – Summary Statistics

The table reports statistics that describe our main sample. Panel A reports the statistics for the first sample of 130 countries that report credit market indicators, while panel B shows the statistics for the second sample of 82 countries that report equity market indicators. *R&D/GDP* is the amount of R&D expenditures scaled by GDP. *# of Researchers* is the number of researchers in R&D per million population. *Bank Credit* is the amount of domestic credit offered by banks as a percent of GDP. *Finance Credit* is the amount of domestic credit offered by the financial sector as a percent of GDP. *Private Credit* is the amount of domestic credit offered to the private as the percent of GDP. *GDP/Capita* is the amount of gross domestic product per capita. *NETEX* is the difference (in millions) between total exports and total imports. *Savings/GDP* is the amount of gross savings scaled by GDP. *Gov't Spending* is the amount (in millions) of national expenditures in U.S. dollars. *Cap. Formation* is the amount of capital formation (in millions) in U.S. dollars. *MCAP/GDP* is the amount of market capitalization for all publicly traded companies in a particular country as a percent of GDP. *Volume/GDP* is the amount of dollar trading volume for all stocks (both domestic and foreign) scaled by GDP. *Turnover* is amount of domestic shares traded scaled by market capitalization.

Panel A. Credit Market Indicators and Controls (first sample of 130 countries)					
	Mean	Std. Deviation	Minimum	Median	Maximum
	[1]	[2]	[3]	[4]	[5]
R&D/GDP	0.9345	0.9314	0.0054	0.5703	4.4055
# of Researchers	1,963.80	1,874.81	5.85	1,433.60	8,255.40
Bank Credit	34.24	33.77	0.08	22.99	312.12
Finance Credit	49.13	53.95	-114.69	35.42	2,066.18
Private Credit	36.32	36.1	0.08	24.02	312.12
GDP/CAPITA	16,563.41	19,714.87	138.93	7,723.72	119,225.38
NETEX	2.01	72.76	-770.94	-0.39	385.50
Savings/GDP	22.33	14.93	-37.01	21.92	74.34
Gov't Spending	622.98	1,876.88	0.69	85.91	18,644.80
Cap. Formation	153.37	468.09	0.00	21.3	5,023.46
Panel B. Equity Market Indicators and Controls (second sample of 82 countries)					
R&D/GDP	1.2037	0.9644	0.0074	0.8995	4.4055
# of Researchers	2,282.84	1,722.10	17.41	1,947.72	8,255.40
MCAP/GDP	68.60	116.95	0.01	41.72	1,254.47
Volume/GDP	43.46	79.39	0.0026	16.40	952.67
Turnover	59.69	86.11	0.05	40.35	1,721.54
GDP/CAPITA	21,612.26	20,515.46	382.92	15,804.04	119,225.38
NETEX	1.04	88.87	-770.94	0.10	385.50
Savings/GDP	25.40	10.69	-35.32	24.17	58.40
Gov't Spending	926.93	2,255.70	4.204	214.43	18,644.80
Cap. Formation	228.82	563.92	0.03	49.94	5,023.46

Table 2 – Correlation Matrices

Panel A reports the Pearson correlation coefficients for each of the variables used in the analysis for the first sample of 130 countries that report credit market indicators. Panel B reports Pearson correlation coefficients for the same variables, but for the second sample of 82 countries that report equity market indicators. *R&D/GDP* is the amount of R&D expenditures to GDP. *# of Researchers* is the number of researchers in R&D per million populations. *Bank Credit* is the amount of domestic credit offered by banks as a percent of GDP. *Finance Credit* is the amount of domestic credit offered by the financial sector as a percent of GDP. *Private Credit* is the amount of domestic credit offered to the private as the percent of GDP. *GDP/Capita* is the amount of gross domestic product per capita. *NETEX* is the difference (in millions) between total exports and total imports. *Savings/GDP* is the amount of gross savings scaled by GDP. *Gov't Spending* is the amount (in millions) of national expenditures in U.S. dollars. *Cap. Formation* is the amount of capital formation (in millions) in U.S. dollars. *MCAP/GDP* is the amount of market capitalization for all publicly traded companies in a particular country as a percent of GDP. *Volume/GDP* is the amount of dollar trading volume for all stocks (both domestic and foreign) scaled by GDP. *Turnover* is amount of domestic shares traded scaled by market capitalization. In parentheses, we report p-values that test whether or not the correlation is reliably different from zero. *, **, and *** denote statistical significance at the 0.10, 0.05, and 0.01 levels, respectively.

Panel A. Credit Market Indicators and Controls (first sample of 130 countries)

	R&D/GDP	*# of Researchers*	*Bank Credit*	*Finance Credit*	*Private Credit*	*GDP/Capita*	*NETEX*	*Savings/GDP*	*Gov't Spending*	*Cap. Formation*
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
R&D/GDP	1.0000									
# of Researchers	0.9061***	1.0000								
	(<.0001)									
Bank Credit	0.5348***	0.5571***	1.0000							
	(<.0001)	(<.0001)								
Finance Credit	0.6284***	0.6079***	0.8530***	1.0000						
	(<.0001)	(<.0001)	(<.0001)							
Private Credit	0.5901***	0.5853***	0.9420***	0.9257***	1.0000					
	(<.0001)	(<.0001)	(<.0001)	(<.0001)						
GDP/Capita	0.6279***	0.7269***	0.6079***	0.6405***	0.6325***	1.0000				
	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)					
NETEX	-0.0378	-0.0009	0.1069***	-0.1201***	-0.1293***	-0.0283	1.0000			
	(0.1550)	(0.9779)	(<.0001)	(<.0001)	(<.0001)	(0.2878)				
Savings/GDP	0.2167***	0.2549***	0.2859***	0.1825***	0.2587***	0.4197***	0.2275***	1.0000		
	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)			
Gov't Spending	0.3896***	0.2264***	0.1575***	0.4593***	0.4285***	0.2618***	-0.5689***	0.0486*	1.0000	
	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(0.0691)		
Cap. Formation	0.3681***	0.1798***	0.1901***	0.4309***	0.4079***	0.2046***	-0.3478***	0.1178***	0.9331***	1.0000
	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	

Panel B. Equity Market Indicators and Controls (second sample of 82 countries)										
	R&D/GDP	*# of Researchers*	*MCAP/GDP*	*Volume/GDP*	*Turnover*	*GDP/Capita*	*NETEX*	*Savings/GDP*	*Gov't Spending*	*Cap. Formation*
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
R&D/GDP	1.0000									
# of Researchers	0.8692*** (<.0001)	1.0000								
MCAP/GDP	0.1141*** (0.005)	0.2146*** (<.0001)	1.0000							
Volume/GDP	0.2597*** (<.0001)	0.2804*** (<.0001)	0.8326*** (<.0001)	1.0000						
Turnover	0.2287*** (<.0001)	0.2157*** (<.0001)	0.0198 (0.5537)	0.3071*** (<.0001)	1.0000					
GDP/Capita	0.5035*** (<.0001)	0.7308*** (<.0001)	0.2380*** (<.0001)	0.2186*** (<.0001)	0.0668** (0.0454)	1.0000				
NETEX	-0.0459 (0.1634)	-0.0130 (0.7167)	-0.0318 (0.3340)	-0.1908*** (<.0001)	-0.0823** (0.0138)	-0.0569* (0.0839)	1.0000			
Savings/GDP	0.1690*** (<.0001)	0.2783*** (<.0001)	0.1916*** (<.0001)	0.1332*** (<.0001)	0.0254 (0.4499)	0.3364*** (<.0001)	0.3020*** (<.0001)	1.0000		
Gov't Spending	0.3868*** (<.0001)	0.2427*** (<.0001)	0.0639* (0.0531)	0.3688*** (<.0001)	0.3287*** (<.0001)	0.2262*** (<.0001)	-0.5889*** (<.0001)	-0.0360 (0.2761)	1.0000	
Cap. Formation	0.3619*** (<.0001)	0.1876*** (<.0001)	0.0504 (0.1270)	0.3501*** (<.0001)	0.3491*** (<.0001)	0.1608*** (<.0001)	-0.3613*** (<.0001)	0.0793** (0.0163)	0.9305*** (<.0001)	1.0000

Table 3 – Multivariate Tests – Credit Markets and R&D Expenditures

The table reports the results from estimating the following equation using OLS:

$$\ln(R\&D/GDP)_{i,t} = \beta_0 + \beta_1 Credit^{j}_{i,t} + \beta_2\, GDP/Capita_{i,t} + \beta_3 NETEX_{i,t} + \beta_4 Savings/GDP_{i,t} + \beta_5 Gov't\ Spending_{i,t} + \beta_6 Cap.Formation_{i,t} + \varepsilon_{i,t},$$

where the dependent variable is the natural log of the ratio of R&D expenditures and GDP (*R&D/GDP*). The independent variable of interest is one of three variables. First, we include the natural log of the domestic credit (as a percent of GDP) that is offered by banks (*Bank Credit*). Second, we include the natural log of domestic credit (as a percent of GDP) that is offered by the financial sector (*Finance Credit*). Third, we include the natural log of domestic credit (as a percent of GDP) that is offered to the private (*Private Credit*). The control variables include the following: *GDP/Capita* is the amount of gross domestic product per capita. *NETEX* is the difference (in millions) between total exports and total imports. *Savings/GDP* is the amount of gross savings scaled by GDP. *Gov't Spending* is the amount (in millions) of national expenditures in U.S. dollars. *Cap. Formation* is the amount of capital formation (in millions) in U.S. dollars. We include year fixed effects in each of the specifications. In parentheses, we report t-statistics that are obtained from robust standard errors. *, **, and *** denote statistical significance at the 0.10, 0.05, and 0.01 levels, respectively.

	[1]	[2]	[3]	[4]	[5]	[6]
Bank Credit	0.5686***	0.1220**				
	(7.15)	(2.42)				
Finance Credit			0.6156***	0.2053***		
			(7.74)	(3.26)		
Private Credit					0.5759***	0.1035**
					(7.34)	(2.20)
Adjusted R^2	0.2305	0.4270	0.2846	0.4668	0.2441	0.4253
Controls	No	Yes	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	1,425	1,400	1,396	1,372	1,425	1,400

Table 4 – Multivariate Tests – Credit Markets and R&D Researchers

The table reports the results from estimating the following equation using OLS:

$$\ln(\#\ of\ Researchers)_{i,t} = \beta_0 + \beta_1 Credit^{j}_{i,t} + \beta_2\ GDP/Capita_{i,t} + \beta_3 NETEX_{i,t} + \beta_4\ Savings/GDP_{i,t} + \beta_5 Gov't\ Spending_{i,t} + \beta_6 Cap.Formation_{i,t} + \varepsilon_{i,t},$$

where the dependent variable is the natural log of the number of R&D researchers per million population in a particular country for country i in year t (*# of Researchers*). The independent variable of interest is one of three variables. First, we include the natural log of the domestic credit (as a percent of GDP) that is offered by banks (*Bank Credit*). Second, we include the natural log of domestic credit (as a percent of GDP) that is offered by the financial sector (*Finance Credit*). Third, we include the natural log of domestic credit (as a percent of GDP) that is offered to the private (*Private Credit*). The control variables include the following: *GDP/Capita* is the amount of gross domestic product per capita. *NETEX* is the difference (in millions) between total exports and total imports. *Savings/GDP* is the amount of gross savings scaled by GDP. *Gov't Spending* is the amount (in millions) of national expenditures in U.S. dollars. *Cap. Formation* is the amount of capital formation (in millions) in U.S. dollars. We include year fixed effects in each of the specifications. In parentheses, we report t-statistics that are obtained from robust standard errors. *, **, and *** denote statistical significance at the 0.10, 0.05, and 0.01 levels, respectively.

	[1]	[2]	[3]	[4]	[5]	[6]
Bank Credit	1.1647***	0.2280***				
	(14.68)	(3.99)				
Finance Credit			1.1589***	0.3019***		
			(14.95)	(4.92)		
Private Credit					1.1483***	0.2035***
					(15.18)	(3.61)
Adjusted R^2	0.3834	0.6320	0.4114	0.6457	0.3947	0.6304
Controls	No	Yes	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	1,021	1,007	998	985	1,021	1,007

Table 5 – Multivariate Tests – Equity Markets and R&D Expenditures

The table reports the results from estimating the following equation using OLS:

$$\ln(R\&D/GDP)_{i,t} = \beta_0 + \beta_1 Equity^{j}_{i,t} + \beta_2\, GDP/Capita_{i,t} + \beta_3 NETEX_{i,t} + \beta_4 Savings/GDP_{i,t} + \beta_5 Gov't\ Spending_{i,t} + \beta_6 Cap.Formation_{i,t} + \varepsilon_{i,t},$$

where the dependent variable is the natural log of the ratio of R&D expenditures and GDP (*R&D/GDP*). The independent variable of interest is one of three equity variables. First, we include the natural log of the ratio of market capitalization for all publicly traded stocks (both domestic and foreign) to GDP (*MCAP/GDP*). Second, we include the natural log of the dollar volume of all shares traded scaled by GDP (*Volume/GDP*). Third, we include the natural log of all shares traded on domestic markets scaled by market capitalization (*Turnover*). The control variables include the following: *GDP/Capita* is the amount of gross domestic product per capita. *NETEX* is the difference (in millions) between total exports and total imports. *Savings/GDP* is the amount of gross savings scaled by GDP. *Gov't Spending* is the amount (in millions) of national expenditures in U.S. dollars. *Cap. Formation* is the amount of capital formation (in millions) in U.S. dollars. We include year fixed effects in each of the specifications. In parentheses, we report t-statistics that are obtained from robust standard errors. *, **, and *** denote statistical significance at the 0.10, 0.05, and 0.01 levels, respectively.

	[1]	[2]	[3]	[4]	[5]	[6]
MCAP/GDP	0.3212***	0.0177				
	(11.94)	(0.71)				
Volume/GDP			0.2496***	0.1059***		
			(16.36)	(8.12)		
Turnover					0.3076***	0.1678***
					(11.20)	(9.91)
Adjusted R^2	0.1157	0.5118	0.2384	0.4930	0.1897	0.5726
Controls	No	Yes	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	926	918	1,026	1,016	899	889

Table 6 – Multivariate Tests – Equity Markets and R&D Researchers

The table reports the results from estimating the following equation using OLS.

$$\ln(\#\ of\ Researchers)_{i,t} = \beta_0 + \beta_1 Equity_{i,t}^{j} + \beta_2\ GDP/Capita_{i,t} + \beta_3 NETEX_{i,t} + \beta_4 Savings/GDP_{i,t} + \beta_5 Gov't\ Spending_{i,t} + \beta_6 Cap.Formation_{i,t} + \varepsilon_{i,t},$$

The dependent variable is the natural log of the number of R&D researchers per million population in a particular country for country i in year t (*# of Researchers*). The independent variable of interest is one of three equity variables. First, we include the natural log of the ratio of market capitalization for all publicly traded stocks (both domestic and foreign) to GDP (*MCAP/GDP*). Second, we include the natural log of the dollar volume of all shares traded scaled by GDP (*Volume/GDP*). Third, we include the natural log of all shares traded on domestic markets scaled by market capitalization (*Turnover*). The control variables include the following: *GDP/Capita* is the amount of gross domestic product per capita. *NETEX* is the difference (in millions) between total exports and total imports. *Savings/GDP* is the amount of gross savings scaled by GDP. *Gov't Spending* is the amount (in millions) of national expenditures in U.S. dollars. *Cap. Formation* is the amount of capital formation (in millions) in U.S. dollars. We include year fixed effects in each of the specifications. In parentheses, we report t-statistics that are obtained from robust standard errors. *, **, and *** denote statistical significance at the 0.10, 0.05, and 0.01 levels, respectively.

	[1]	[2]	[3]	[4]	[5]	[6]
MCAP/GDP	0.3187***	-0.1547				
	(8.40)	(-5.06)				
Volume/GDP			0.2459***	0.0562***		
			(12.66)	(3.32)		
Turnover					0.2398***	0.1080***
					(6.58)	(5.01)
Adjusted R^2	0.0776	0.6018	0.1649	0.5457	0.0810	0.6259
Controls	No	Yes	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	782	780	870	868	765	763

Table 7 – R&D and the Adoption of the Euro: Difference-in-Differences Analysis

The table reports the results from estimating the following equation using OLS:

$$\ln(R\&D/GDP)_{i,t} \; or \; \ln(\#\; of\; Researchers)_{i,t} = \beta_0 + \beta_1 Euro_i + \beta_2 Post_t + \beta_3 Euro_i \times Post_t + \beta_4\, GDP/Capita_{i,t} + \beta_5 NETEX_{i,t} + \beta_6 Savings/GDP_{i,t} + \beta_7 Gov't\; Spending_{i,t} + \beta_8 Cap.Formation_{i,t} + \varepsilon_{i,t}\,,$$

where the dependent variable is one of two measures: First, the dependent variable in columns [1] and [2] is the natural log of the ratio of R&D expenditures and GDP (*R&D/GDP*). Second, the dependent variable in columns [3] and [4] is the natural log of the number of R&D researchers per million population in country *i* in year *t* (*# of Researchers*). The independent variables of interest are three variables. *Euro* is an indicator variable capturing whether or not the European country in question is one of the 11 original countries that adopted the euro beginning in 1999. *Post* is an indicator variable capturing the period from 1999 to the end of the sample time period. *Euro×Post* is the interaction between the two indicator variables and the difference-in-difference estimator. The control variables include the following: *GDP/Capita* is the amount of gross domestic product per capita. *NETEX* is the difference (in millions) between total exports and total imports. *Savings/GDP* is the amount of gross savings scaled by GDP. *Gov't Spending* is the amount (in millions) of national expenditures in U.S. dollars. *Cap. Formation* is the amount of capital formation (in millions) in U.S. dollars. We include year fixed effects in each of the specifications. In parentheses, we report t-statistics that are obtained from robust standard errors. *, **, and *** denote statistical significance at the 0.10, 0.05, and 0.01 levels, respectively.

	R&D/GDP		# of Researchers	
	[1]	[2]	[3]	[4]
Euro	0.6937***	-0.2679***	0.2606*	-0.4097***
	(5.63)	(-2.94)	(1.72)	(-3.20)
Post	-0.0523	-0.4515***	0.0628	-0.1855
	(-0.51)	(-6.50)	(0.45)	(-1.60)
Euro x Post	0.2460*	0.3986***	0.3862**	0.3661***
	(1.81)	(4.15)	(2.36)	(2.70)
Adjusted R^2	0.2133	0.5599	0.1326	0.5998
Controls	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes
N	667	665	542	542