FINANCE, INNOVATION, AND COMPARATIVE ADVANTAGE

FINANCIAL DEVELOPMENT AND INTERNATIONAL TRADE IN FINANCE DEPENDENT AND INNOVATION DEPENDENT INDUSTRIES: A GLOBAL PERSPECTIVE

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Abstract:

We find that financial development is a key enabler in comparative advantage in international trade, in finance and innovation dependent industries. Countries with well-functioning financial institutions better enable firms that are dependent on external funding and innovations. Furthermore, the level of comparative advantage in finance dependent industries is largely attributed to an underlying innovation dependence. We use a model of Ricardian comparative advantage originally developed by Costinot (2009) and calibrate industry-level innovation dependence following Sampson (2023), to explain our findings. We primarily use data from OECD STAN and ANBERD databases and US Compustat databases.

Keywords:

Trade, Financial Development, Innovation, Finance Dependence, Exports

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1 Introduction

A vast amount of literature has established a significant impact of financial frictions on the macroeconomy in terms of economic growth (King and Levine, 1993; Rajan and Zingales, 1998; Brown, Fazzari, and Petersen, 2009), total factor productivity (Midrigan and Xu, 2014), and resource allocation (Cole, Greenwood, and Sanchez, 2016). Recently, research has increasingly explored the implications of these frictions on international trade, identifying financial development as a key enabler of comparative advantage in finance dependent sectors (see e.g. Manova, 2013; Leibovici, 2021; Ebrahimian and Firooz, 2023). Following recent years' rapid development in technological advancements and innovation generation, the R&D investment by firms has become an increasingly impactful factor when analyzing their comparative advantage in international trade (Sampson, 2023). Furthermore, studies within finance and economics have in recent years introduced an increased interest in the role of finance in technological development (Howell, 2017).

This paper investigates how industries' dependence on external finance and innovation shape comparative advantage in the context of international trade. We also examine how financial development enables the comparative advantage in these sectors. Lastly, this study examines the degree to which comparative advantage in finance dependent industries can be attributed to the reliance on innovation.

Previous studies provide empirical support for these relationships. Ebrahimian and Firooz (2023) show that financial development facilitates comparative advantage in finance-dependent industries by easing access to external capital, but only when trade barriers are low. Furthermore, Sampson (2023) finds that countries that are more R&D efficient have a comparative advantage in innovation dependent industries. Additionally, financially dependent industries are also shown to benefit from innovation, exemplified by Acharya and Xu (2017) who find that publicly listed firms in external-finance dependent industries reap greater benefits from R&D investment due to the crucial role of access to external capital. While there is extensive research on both how financial development (Ebrahimian and Firooz, 2023) and innovation dependence (Sampson, 2023) each enable comparative advantage, to the best of our knowledge, no study explores their interaction systematically across countries.

To empirically investigate how financial development influences comparative advantage in industries that are more dependent on external finance and innovation, we build upon the Ricardian trade framework by Costinot (2009). In this framework, countries specialize in industries where they are relatively more productive, conditional on their institutional quality. We extend this model by integrating sector-specific measures of external-finance dependence, based on Rajan and Zingales (1998), and innovation dependence, calibrated following Sampson (2023). We interpret external-finance- and innovation-dependent industries as "complex industries" within Costinot's (2009) framework and use financial development as the enabler of comparative advantage. We hypothesize that financial development facilitates comparative advantage in these sectors, and that innovation dependence drives part of the already observed comparative advantage in finance dependent industries (see e.g. Leibovici, 2021; Ebrahimian and Firooz, 2023). To test these hypotheses, we employ a two-stage empirical approach.

First, to confirm these findings, we estimate revealed comparative advantage by regressing bilateral trade flows on industry-level finance dependence, while controlling for industry-exporter and importer-exporter fixed effects. We then regress the resulting comparative advantage coefficients on country-level financial development.

Secondly, we extend this framework to explore whether financial development also facilitates comparative advantage in innovation dependent industries, and whether there is an underlying correlation between finance- and innovation dependence. We estimate revealed comparative advantage by regressing bilateral trade flows on industry-level finance and innovation dependence, again controlling for fixed effects. Subsequently, we regress the updated comparative advantage coefficients on financial development.

This empirical approach allows us to examine how financial development systematically enables comparative advantage in finance and innovation-dependent industries. Furthermore, by comparing the coefficients across the specifications and with and without innovation dependence, we can analyze whether parts of the previously observed effects of financial development on comparative advantage in finance dependent industries are partly driven by innovation dependence.

In our regressions, we use Comtrade bilateral trade data for 165 exporters and 167 importers across 19 manufacturing industries. Consistent with the empirical literature on international trade and comparative advantage, we limit our analysis to manufacturing industries (see, e.g., Rajan and Zingales, 1998; Costinot, 2009; Leibovici, 2021), since these sectors produce tradable goods in most economies and exhibit heterogeneity in capital needs and asset intangibility (Manova, 2013). For robustness tests, we use alternative proxies for financial vulnerability, innovation dependence, and financial development. Proxies for external-finance dependence are asset intangibility and capital intensity. We follow Sampson (2023) and estimate three additional measures of innovation dependence for robustness. Financial development is measured using the log of private credit over GDP and proxied by financial system deposits over GDP. We test both current and lagged values of financial development to account for temporal dynamics and mitigate endogeneity concerns.

First, we confirm previous findings in the literature and show that external finance dependence positively and significantly affects international trade patterns. We also find that financial development enables comparative advantage in external-finance dependent industries. This suggests that countries with more developed financial systems can better support industries that rely on external-finance. A larger demand for external financing can also be directly connected to the sensitivity to the quality of a nation's financial institutions. Specifically, different forms of institutional quality, in our case financial frictions, hinder these firms into entering the international export market (Costinot, 2009).

Second, we show that both finance dependence and innovation dependence are statistically significant determinants of international trade patterns. They reveal heterogeneity in country-level financial development and innovation dependence, suggesting that institutional differences impact comparative advantage. Additionally we demonstrate the enabling role of country-level financial development in finance and innovation dependent industries in the context of comparative advantage in international exports.

Comparative advantages in financially dependent industries are shown to be positively and significantly affected by financial development. Our results also show a significant coefficient of financial development on the comparative advantage innovation dependent industries. The implications are that financial development is shown to be an important determinant for countries that depend heavily on its innovations, and their capacity to convert innovations into comparative advantages in international trade. Implications of such a large and significant relationship between the variables tested also align with the underlying assumptions of our model, as firms within countries with well-developed financial institutions thus choose to allocate resources with the purpose of entering innovation dependent industries.

We find a 16.77% reduction in the standardized coefficient when we regress the comparative advantage of finance dependent industries on financial development when including innovation dependence. This suggests that part of the initial effect of financial development on comparative advantage in financially dependent sectors is explained by innovation dependence. Without including innovation dependence, the role of financial development on comparative advantage in external-finance dependent industries risks being overstated.

We perform a set of robustness tests across all main variables that confirm these findings. We use financial system deposits as a proxy for financial development, and asset intangibility, and capital intensity as proxies for financial vulnerability. Additionally, we estimate three other proxies for innovation dependence using different specifications, that differ by controls. To strengthen the identification of causal effects, we introduce exporter-industry and importer-industry fixed effects, as well as 5-year and 10-year lagged financial development in our robustness specifications.

This study contributes to a large body of literature on how financial frictions distort bilateral trade flows (Do and Levchenko, 2007; Amiti and Weinstein, 2011; Manova, 2013, Acharya and Xu, 2017; Ebrahimian and Firooz, 2023). For example, Manova (2013) finds a significant effect on how financial development supports a country's ability to develop comparative advantage in finance dependent sectors. Ebrahimian and Firooz (2023) adds to these findings by demonstrating that this effect is only present when trade barriers are low. Further contributions to this research emphasize the significant effect of financial development on a country's ability to develop growth through its advancements in sectors with a larger scale of operations (Buera and Kaboski, 2011). Buera and Kaboski (2011) find a significant effect of financial frictions on total factor productivity (TFP) in sectors with varying degrees of operational nature, highlighting the importance of industry characteristics in shaping the effect of financial development. Although this study also incorporates financial development and finance dependence in the initial regression, we further examine the effect of industry-level comparative advantage in innovation-dependent industries and how it is affected by financial development. Our study adds to this literature by including innovation dependency as a channel through which financial development shapes comparative advantage.

Additionally, this paper contributes to the literature on how comparative advantage in international trade is determined through inherent endogenous productivity differences across countries based on the heterogeneous firm model as developed by Melitz (2003) and Costinot (2009). Specifically, Costinot's (2009) framework is used to estimate country-level comparative advantage in the context of international trade. Countries with higher institutional quality and higher human capital per worker produce more complex goods and are thus also competitive in the export market within that specific good (Melitz, 2003; Costinot, 2009). In particular, we derive country and industry-level comparative advantage, and its dependency on the financial development of a country by applying Costinot's (2009) framework, implying that institutional differences lead to different optimal organization of production between nations, and that these endogenous differences lead to comparative advantages. In our study, we incorporate financial development as an enabling variable following the logic that productivity and export competitiveness in finance and innovation dependent industries may be mediated by access to finance.

Furthermore, our study contributes to the growing literature on how innovation is affected by financial development, (see e.g. Eaton and Kortum, 2002; Atkeson and Burstein, 2010; Acemoglu and Restrepo, 2018; Perla, Tonetti, and Waugh, 2021; Sampson, 2023). While Sampson (2023) acknowledges the role of financial development as a control variable in explaining technology gaps, his focus is primarily on how R&D efficiency, rather than financial development, influence the comparative advantage of innovation dependent sectors in the context of international trade. In contrast, this study introduces financial development as a primary enabler of comparative advantage of financial dependent and innovation dependent countries, as opposed to treating it as a control variable, making it a central part of the investigation. Following previous research, this study incorporates the hypothesis that sectoral differences in innovation dependency generate Ricardian comparative advantage (Sampson, 2023).

While earlier studies have mentioned financial vulnerability related to innovators (Rajan and Zingales, 1998) and linked asset intangibility to financial dependence (Manova, 2013), they do not explicitly control for innovation when estimating comparative advantage. Brown, Martinsson, and Petersen (2013) argue that this is important because R&D activities create financial frictions, such as long-term investment horizons and low collateral value. These frictions are not captured by capital expenditure measures (Brown, et al., 2013), such as external-finance dependence by Rajan and Zingales (1998), which is widely used for measuring financial vulnerability (see e.g. Manova, 2013; Aretz, Campello, and Marchica, 2021; Ebrahimian and Firooz, 2023). Recently, Sampson (2023) offers a framework that investigates how cross-country differences in R&D efficiency give rise to technology gaps, differences in income, and comparative advantage. He introduces the concept of innovation dependence and shows that countries with more efficient innovation systems specialize in more innovation-intensive sectors and experience higher wages and exports in those sectors. Our study builds on this framework and addresses the gap identified by Brown, Martinsson, and Petersen (2013) by giving new empirical evidence that suggests that a substantial portion of observed comparative advantage in finance dependent sectors is in part driven by underlying innovation dependence. In this sense, we complement prior studies and clarify the micro-foundations of how financial development enables comparative advantage in innovation dependent sectors, which is an effect that has typically been attributed to only finance dependence.

2 Theoretical Framework

2.1 Costinot's (2009) Ricardian Model of Comparative advantage

The empirical framework used in this paper is based on Costinot's (2009) Ricardian model of comparative advantage, where he extends the classical Ricardian theory by incorporating industry-specific institutional frictions that influence countries' productivity in each industry. In this framework, comparative advantage arises from endogenous productivity differences that vary across both countries and sectors, rather than being driven by exogenous technological differences alone. Costinot's (2009) model predicts that countries will specialize in industries where they are relatively more productive, given their institutional and structural characteristics.

In Costinot's (2009) model, each good differs in complexity, defined as the number of distinct tasks required to produce one unit of output. In more complex industries, a greater number of tasks must be performed, requiring each worker to acquire more knowledge and skill than if he were to perform them alone. However, specializing workers on fewer tasks reduces training costs and increases efficiency since each worker spends less time learning and more time producing. This means that greater complexity offers greater potential gains from specialization. On the other hand, these gains are only realized if contracts between workers and firms are effectively enforced. This process depends on the country's institutional quality. If institutions are weak, enforcing many contracts becomes difficult and productivity decreases. As a result, countries with better institutional quality are more likely to specialize in complex industries where gains from specialization are large but require strong enforcement mechanisms.

The key mechanism in Costinot's (2009) framework is the trade-off between returns to specialization and transaction costs. On one hand, assigning tasks to specialized workers increases productivity, but on the other hand, doing so requires more contracts. Both of these functions might suffer from weaker institutions since contract enforcement becomes weaker. Costinot (2009) shows that countries with stronger institutions are better able to enforce complex contracts and thus support larger teams, enabling them to specialize in more complex industries.

We interpret finance- and innovation-dependent industries as structurally similar to complex industries in Costinot's model. Finance dependent industries rely on contracts that secure access to debt and capital (Manova, 2013), and are complex in terms of skill intensity and demand for human capital (Philippon and Reshef, 2012). Innovation-dependent industries are also closely similar to Costinot's definition of complex industries. According to Sampson (2023), industries with high innovation dependence are complex due to their reliance on tacit knowledge and exhibit less advantage of backwardness, meaning that it is harder for countries to "catch up" through imitation or adoption. Innovation dependent industries are also characterized by more localized knowledge spillovers which implies that they are more reliant on domestic institutions (Sampson, 2023). We interpret this as a greater need for developed institutions, as effective innovation in these sectors depends on strong contract enforcement to facilitate the sharing of ideas, protect intellectual property, and manage collaborative efforts such as joint R&D projects. Thus, we hypothesize that comparative advantage in these industries depends on high institutional quality to support these complex activities. To investigate how a country's financial systems affect specialization in these industries, we follow Ebrahimian and Firooz (2023) and proxy institutional quality as financial development. Unlike Costinot (2009) who focuses on legal enforceability as a friction, our approach focuses on the role of financial frictions, such as firms' ability to finance capital and knowledge-intensive activities.

2.2 Sampson's (2023) Theoretical Framework of Innovation Dependence

To analyze how innovation shapes international trade patterns, we follow the methodology developed by Sampson (2023), who introduces a framework in which industries differ in their dependence on innovation. Innovation dependence is defined as the elasticity of industry productivity with respect to a country's R&D efficiency. R&D efficiency, in turn, is defined as how well a country transforms R&D investments (inputs) into productivity (outputs).

In Sampson's (2023) theoretical framework, firms are heterogeneous in their ability to innovate. Firms differ in their ability to conduct R&D, and in equilibrium, only those with capabilities above a certain threshold engage in R&D. The innovation threshold, and therefore the share of innovative firms in a country, depends on the country's R&D efficiency. Where R&D efficiency is higher, the threshold for engaging in innovation is lower. When aggregated, these firm-level results create a measure of a country's effective innovation capacity in a given industry, denoted by Ψ_o^i. Innovation dependence is then expressed as:

$$[\text{ID}]^i = \frac{1+\kappa_i}{\gamma_i} + \left((1-\beta) - \frac{\alpha(1+\kappa_i)}{\gamma_i}\right) \times \frac{\partial \log \Psi_o^i}{\partial \log B_o}, \tag{1}$$

where κ_i is the degree of localization of knowledge spillovers, i.e. the degree to which knowledge stays within the country, γ_i is the advantage of backwardness parameter, which indicates how easy it is for less productive firms to "catch up". The variables β and α are the returns to scale in production and R&D respectively. Ψ_o^i is the effective innovation capability of country o in industry i, and B_o is the R&D efficiency of country o. Since many variables in this expression are theoretical and not directly observable, Sampson (2023) estimates innovation dependence using a gravity model, exploiting trade flows and cross-country differences in R&D efficiency. A higher value of $[\text{ID}]^i$ implies that an industry's trade and productivity outcomes are more sensitive to national differences in R&D performance. For a detailed description of the calibration method, see Appendix A, or Sampson (2023).

3 Data

We use multiple data sources to empirically investigate how financial development impacts the comparative advantage of industries with high finance and innovation dependence, following the methodologies of Rajan and Zingales (1998), Ebrahimian and Firooz (2023), and Sampson (2023).

To estimate comparative advantage in finance- and innovation dependent industries, we use bilateral trade flow data from the study by Ebrahimian and Firooz (2023), which is originally sourced from Comtrade.

To minimize circularity and reinforce the external validity of our findings, we employ a different source of trade data when estimating innovation dependence. Specifically, all data used to estimate innovation dependence comes from Sampson's (2023) replication package. Sampson (2023) uses trade data from the OECD STAN's "Bilateral Trade by Industry and End-use" dataset when estimating innovation dependence.

Data on R&D expenditure by industry are sourced from the OECD ANBERD database, which provides data for 20 two-digit ISIC rev 4 manufacturing industries. Sampson (2023) notes missing observations at the two-digit industry level in the ANBERD database. To address these gaps, the data is aggregated across the period 2010–2014, keeping only countries reporting R&D intensity for at least two-thirds of industries per year. This results in a final sample of 22 ISIC Rev. 4 industries. Industry value-added and output data for the same period, 2010–2014, are sourced from the OECD STAN database. Consistent with Sampson (2023), R&D data explicitly exclude adoption-related investments, aligning with OECD's definition of R&D as "work undertaken to increase the stock of knowledge. . . and devise new applications of knowledge." Standard gravity variables come from the CEPII gravity dataset (Head and Thierry, 2014). Additional macroeconomic and institutional control variables are drawn from multiple sources, including the Penn World Tables (Feenstra, Inklaar, and Timmer, 2017), IMF's International Financial Statistics (IMF, 2018), and various World Bank datasets, specifically, the World Development Indicators, Worldwide Governance Indicators, Financial Structure database, and Doing Business reports (Čihák et al., 2012; World Bank, 2018a,b; 2021). Following Sampson (2023), we estimate three additional proxies for innovation dependence: In Dep 1, In Dep 2, and In Dep 4. The proxy In Dep 1 is the estimate of innovation dependence without any additional control variables except for trade cost controls[1]. Despite contributing to the robustness of the regression, In Dep 1 risks overstating the effect of innovation since it does not control for factors such as institutional quality or economic structure that could shape trade flows and correlate with innovation dependence (Sampson, 2023). The proxy In Dep 2 consists of the innovation dependence measure, trade costs controls, and productivity-related controls to account for differences in institutional quality across importing countries[2]. This set of controls serves as a proxy for allocative efficiency which Sampson (2023) defines as the extent to which a country's institutional framework supports the effective usage of investments in innovation. In Dep 3 is used as the main variable for our first-stage regression. It consists of the baseline R&D measure and includes trade cost controls, productivity-related controls as well as controls for alternative sources of comparative advantage unrelated to R&D efficiency[3]. These controls capture comparative advantages arising from financial development (Manova, 2023), institutional quality (Nunn, 2007), and Heckscher-Ohlin effects (Romalis, 2004). Finally, the proxy In Dep 4 is estimated using patenting-activity based R&D efficiency with the full set of controls [4].

Our main measure for financial vulnerability is external-finance dependence. It is a commonly used proxy for sector-level financial vulnerability and is measured as the share of capital expenditures not financed by internal cash flow (Rajan and Zingales, 1998). Our dataset comes from Ebrahimian and Firooz (2023) who follow Rajan and Zingales (1998). They use U.S. Compustat data from the 1980s. Using a dataset prior to the estimation period helps avoid reverse causality issues, ensuring that financial development does not influence the calculation of our variable. In the context of analyzing how comparative advantage is affected by the external financial environment, Manova (2013) argues that external-finance dependence is a relevant measure of financial vulnerability. This is because firms that are more dependent on external financing for capital expenditure

[1]This set of controls include exporter-industry fixed effects and interactions of industry indicators with a standard set of gravity variables, consisting of six distance intervals, shared border, common language, and free trade dummies (Sampson, 2023).

[2]These controls are rule of law, control of corruption, government effectiveness, political stability, regulatory quality, voice and accountability variables from the Worldwide governance indicators (Sampson, 2023). This set of controls also includes the business environment measured by the Doing Business distance to frontier score (2023) and financial development (log of private credit over GDP)(Sampson, 2023).

[3]These include importer's rule of law, log of private credit to GDP, and human capital (Sampson, 2023).

[4]See footnote 3. Calibration of patenting-activity is presented in appendix A.1

are more affected by financial development. We also use two additional proxies for robustness: asset intangibility and capital intensity in production, which are also sourced from Ebrahimian and Firooz (2023), who originally obtained the data from the NBER-CES Manufacturing Industry Database. Asset intangibility is a common proxy for financial vulnerability. The intuition behind this is that firms with few tangible assets and many intangible assets are more vulnerable to eventual financial risks, since they lack the opportunity to collateralize tangible assets in the event of immediate need for cash (Ebrahimian and Firooz, 2023). Thus, these firms are in need to ensure future cash flow, and are in higher demand for sophisticated institutions (Brown et. al., 2013; Ebrahimian and Firooz, 2023). Capital intensity is calculated as one minus the share of material and labor in sales. The intuition is that higher levels of financing is required in order to fund capital investment, therefore indirectly making capital-intensive firms more dependent on external financing. Consistent with our main measure, both alternative measures are calculated with pre-sample period data from the 1980s to avoid reverse causality issues (Ebrahimian and Firooz, 2023).

Country-level financial development is measured using private credit to GDP as our main proxy for financial development. We also use financial system deposits to GDP as a proxy. We follow Ebrahimian and Firooz (2023) and collect country-level annual data for the main measure and three financial development proxies from the World Bank Group Financial Structure Database (Beck, Demirgüc-Kunt and Levine, 2000). After excluding countries with incomplete trade or financial vulnerability data, the final dataset includes 165 exporting countries and 167 importing countries.

The original datasets used for this study contain different industry classification systems. To ensure consistency across datasets, we map industry classification codes from ISIC Rev. 2 to ISIC Rev. 4 based on economic activities. This allows us to use data sources with different industry codes and enables comparison across trade flows, and finance- and innovation dependence. Details on the industry mapping are described in the appendix B. After mapping, we are left with 19 manufacturing industries at the 2-digit ISIC rev. 4 level. As in the literature on finance dependence and innovation dependence, finance- and innovation dependence are assumed to be constant across countries and years, and only vary across industries (Rajan and Zingales, 1998; Melitz, 2003; Costinot, 2009; Manova, 2013; Ebrahimian and Firooz, 2023; Sampson, 2023). We also restrict the analysis to manufacturing industries since they produce tradable goods and vary in their requirements of external capital investments (Manova, 2013).

Table 1 provides summary statistics for all variables including proxies used in our regression analyses. The main dataset covers 185,838 observations across country-sector pairs for the year 2005. Trade flows exhibit substantial variation, with a mean of approximately 31.8 million USD and a standard deviation of over 470 million USD, indicating the highly skewed nature of international trade data. Financial development captures diverse stages of financial maturity across the sampled countries. Our main measure of innovation dependence, In Dep 3, exhibits limited variance, reflecting the relative stability in industry innovation structures captured by our constructed measure. External finance dependence displays substantial heterogeneity but ranges widely, illustrating diverse financial structures across industries. To reduce the influence of extreme values, we report results between the 10th and 90th percentiles. Summary statistics for finance dependence can be found in Table 1.

Table 2 presents information on four measures of innovation dependence between industries, categorized by ISIC rev. 4 codes. The three measures are R&D efficiency using baseline R&D efficiency[5] with no country or comparative advantage controls, baseline R&D efficiency with country productivity controls, and baseline R&D efficiency with the full set of controls (Sampson, 2023). As observed in Table 2, proxies for innovation dependence exhibit a systematic pattern, where Computer & electronics products (ISIC 26), Machinery & Equipment n. e. c. (ISIC 28) and Chemicals (ISIC 20) have among the highest recorded innovation dependency across all proxies, while consumer product industries such as Coke and refined petroleum products (ISIC 19), Wood, except furniture (ISIC 16) and Food, beverages and tobacco (ISIC 1012) exhibit the lowest recorded levels of innovation dependency. Among the three innovation dependence measures estimated with baseline R&D efficiency, In Dep 3 consistently yields lower estimated values across industries compared to In Dep 1 and In Dep 2. This suggests that when controlling for comparative advantage, a part of the observed innovation dependence is captured by underlying country and industry characteristics.

Table 3 reports the values for our three financial vulnerability proxies in all industries. While external-finance dependence show negative values for certain craft-based industries such as Leather & related products (ISIC 15) and Food, beverages & tobacco (ISIC 1012), indicating lower dependence on external financing, industries with higher demand for innovation and R&D efficiency such as computer & electronic (ISIC 26) and machinery & equipment n.e.c. (ISIC 28) (Sampson, 2023) exhibits high external financial dependence. Asset intangibility reflects inherent industry attributes, where Paper & paper products (ISIC 17) with the lowest value of 0.519 in measured asset intangibility indicates a high reliance on tangible asset within production, while Leather & leather products (ISIC 15), with an asset intangibility value of 0.858, indicates the presence of large intangible assets such as branding, reputation and other goodwill. Compared to the other financial dependency proxies, capital intensity values are significantly lower across all measured industries, with a maximum value of 0.504 for Computer & electronic products (ISIC 26). Furthermore, industries with higher demand for innovation and shorter life cycles such as Computer & electronic products (ISIC 26) exhibit both high external financial and innovation dependence.

[5]Baseline R&D efficiency refers to Sampson's (2023) R&D efficiency calibrated from R&D intensity. R&D intensity is defined as industry R&D expenditure over value added.

Table 1: Summary Statistics for Key Variables (2005)

Variable	**Obs**	**Mean**	**Median**	**Std. Dev.**	**p10**	**p90**
Bilateral trade flow (USD, 1000s)	220,360	31,750.27	93.24	469,384.00	0.52	16,496.49
Private credit to GDP (%)	185,838	53.56	40.12	46.11	10.56	129.89
Financial system deposits to GDP (%)	182,718	48.07	37.99	44.31	9.43	89.38
InDep 1	19	0.569	0.577	0.063	0.479	0.653
InDep 2	19	0.448	0.447	0.062	0.370	0.530
InDep 3	19	0.312	0.295	0.091	0.210	0.380
InDep 4	19	0.311	0.309	0.106	0.209	0.398
External-finance dependence	19	0.186	0.114	0.414	-0.224	0.756
Asset intangibility	19	0.711	0.715	0.088	0.585	0.804
Capital intensity	19	0.366	0.370	0.064	0.272	0.447

Notes: Table 1 Columns report the number of observations, mean, median, standard deviation, 10th percentile, and 90th percentile for each variable used in the empirical analysis. The main dependent variable is bilateral trade flow, measured in thousands of U.S. dollars, and constructed using import data from Comtrade at the country-destination-industry level. Financial development is captured through the two measures private credit to GDP (our primary measure) and financial system deposits to GDP (used as an alternative proxy). Both are measured at the country-year level and expressed in percentage terms. Innovation dependence is proxied using four versions based on the structural R&D framework of Sampson (2023). InDep 1 is constructed using baseline R&D efficiency estimates without country or comparative advantage controls. InDep 2 includes trade cost and country controls, while InDep 3 includes all controls used in the second-stage regressions. InDep 4 is constructed using R&D efficiency derived from patenting activity and includes the full set of controls. External-finance dependence is our primary industry-level proxy for financial vulnerability and is constructed following Rajan and Zingales (1998). Asset intangibility and capital intensity serve as complementary proxies. All three are calculated using U.S. Compustat and NBER-CES manufacturing data from the 1980s, and are treated as fixed technological characteristics at the industry level. Summary statistics are provided for the pool of data at the country by year by three-digit ISIC rev. 2 industry level. All summary statistics are based on the pooled data across all countries, years, and two-digit ISIC rev. 4 industries used in the baseline regression sample for the year 2005.

Table 2: Innovation Dependence Measures by ISIC Industry

R&D efficiency measure:		**R&D Intensity**			**Patenting Activity**
Industry	**ISIC**	**In Dep 1**	**In Dep 2**	**In Dep 3**	**In Dep 4**
Food, beverages & tobacco	1012	0.480	0.359	0.210	0.061
Textiles	13	0.507	0.417	0.286	0.117
Apparel	14	0.473	0.370	0.334	0.131
Leather & related products	15	0.479	0.386	0.340	0.122
Wood, except furniture	16	0.520	0.397	0.201	0.028
Paper & paper products	17	0.580	0.451	0.341	0.127
Printing & media	18	0.579	0.460	0.274	0.109
Coke and refined petroleum products	19	0.479	0.359	0.141	0.053
Chemicals	20	0.587	0.474	0.379	0.187
Basic pharmaceutical products	21	0.622	0.496	0.223	0.168
Rubber & plastic products	22	0.603	0.478	0.376	0.183
Non-metallic minerals	23	0.568	0.447	0.295	0.118
Basic metals	24	0.577	0.425	0.265	0.178
Metal products	25	0.598	0.475	0.333	0.138
Computer & electronic products	26	0.653	0.487	0.599	0.295
Electrical equipment	27	0.606	0.530	0.370	0.185
Machinery & equipment n.e.c	28	0.712	0.599	0.380	0.213
Motor vehicles & trailers	2930	0.558	0.383	0.265	0.092
Furniture & other industries	3133	0.547	0.424	0.254	0.103
Trade cost controls		Yes	Yes	Yes	Yes
Country controls		No	Yes	Yes	Yes
Comparative advantage controls		No	No	Yes	Yes

Notes: Table 2 Industry-level innovation dependence (In Dep 1–4) is constructed following Sampson (2023). Indep 1-3 is estimated using baseline R&D efficiency derived from R&D intensity and In Dep 4 is estimated from R&D efficiency based on patenting activity. The sample is estimated using data 2010 to 2014.

Table 3: Financial Vulnerability Measures by ISIC Industry

Industry	**ISIC**	**external dependence**	**asset intangibility**	**capital intensity**
Food, beverages & tobacco	1012	-0.489	0.685	0.378
Textiles	13	0.205	0.672	0.272
Apparel	14	-0.225	0.842	0.340
Leather & related products	15	-0.530	0.858	0.336
Wood, except furniture	16	0.307	0.680	0.258
Paper & paper products	17	-0.001	0.519	0.313
Printing & media	18	-0.117	0.706	0.465
Coke & refined petroleum products	19	-0.186	0.585	0.230
Chemicals	20	-0.075	0.574	0.347
Basic pharmaceutical products	21	0.732	0.768	0.447
Rubber & plastic products	22	0.073	0.663	0.354
Non-metallic minerals	23	0.044	0.589	0.401
Basic metals	24	0.114	0.618	0.285
Metal products	25	-0.085	0.715	0.370
Computer & electronic products	26	1.043	0.804	0.504
Electrical equipment	27	0.662	0.763	0.408
Machinery & equipment n.e.c	28	0.756	0.788	0.404
Motor vehicles & trailers	2930	0.165	0.724	0.334
Furniture & other products	3133	0.443	0.775	0.383

Notes: Table 3 presents our measures of financial vulnerability for 19 manufacturing industries. All values are retrieved from Ebrahimian and Firooz (2023), where external dependence is the Rajan and Zingales (1998) external-finance dependence, calculated as the fraction of capital expenditures not financed through operational cash flows and capital expenditures. Asset intangibility is calculated as 1 minus the mean of net property, plant, and equipment and scaled by the mean total assets for each firm. For external-finance dependence and asset intangibility, values are presented using the cross-firm median within each industry and data comes from the U.S Compustat database for publicly traded firms in the 1980s. Capital intensity is sourced from the annual NBER-CES Manufacturing Industry database. It is calculated as sales minus production costs divided by sales. All variables are normalized with the U.S. GDP deflator. The original dataset from Ebrahimian and Firooz is presented with ISIC rev 2 codes. We match these to ISIC rev 4 classification codes (see Appendix B for details). In this table, industries are sorted by ISIC rev 4 classification codes.

4 Finance Dependence and Financial Development

We begin the empirical analysis by investigating the relationship between financial development and comparative advantage in finance dependent industries, following Costinot's (2009) two-stage empirical approach.

$$\ln(x)_{\text{od}}^{i} = \alpha_{\text{od}} + \beta_{\text{d}}^{i} + \delta_o[\text{Fin Dep}]^i + \varepsilon_{\text{od}}^{i} \tag{2}$$

where $\ln(x)_{\text{od}}^{i}$ denotes bilateral exports from origin country o to destination d in industry i, and $[\text{Fin Dep}]^i$ is the industry-level external finance dependence. The coefficient of interest is δ_o, and captures the revealed comparative advantage of finance dependent industries.

To interpret this coefficient, we derive the following difference-in-differences expression based on Costinot (2009) and Ebrahimian and Firooz (2023):

$$\text{E}\left[\ln\left(\frac{x_{o_1 d}^{i_1}}{x_{o_1 d}^{i_2}}\right) - \ln\left(\frac{x_{o_2 d}^{i_1}}{x_{o_2 d}^{i_2}}\right)\right] = (\delta_{o_1} - \delta_{o_2}) \cdot \left([\text{Fin Dep}]^{i_1} - [\text{Fin Dep}]^{i_2}\right) \tag{3}$$

This representation shows that countries with higher δ_o will export relatively more in finance dependent industries. In the second-stage, we regress the estimated country-specific δ_o on financial development:

$$\delta_o = \omega_1 + \omega_2 \cdot \log[\text{FinDev}]_o, \tag{4}$$

where $[\text{FinDev}]_o$ is the logarithm of private credit to GDP. Our coefficient of interest is ω_2, which captures the extent to which financial development enables comparative advantage in finance dependent industries. [6]

In the first stage, we find that finance dependence significantly affects trade flows and heterogeneity in the country-level comparative advantage when including innovation dependence. By running the second-stage regression, we find a statistically significant standardized coefficient of 0.644 (t-statistic = 6.33). The R-squared is 0.258, indicating a moderate explanatory power and that other factors might influence comparative advantage in finance dependent industries. This is presented in Table 4.

[6] Standard errors are clustered at the exporter (origin) level. This accounts for correlated error terms within countries exporting across multiple industries. Clustering at this level ensures that our inference reflects the structure of the data and the source of comparative advantage.

Table 4: The Impact of Financial Development on Comparative Advantage in Finance Dependent Industries in 2005

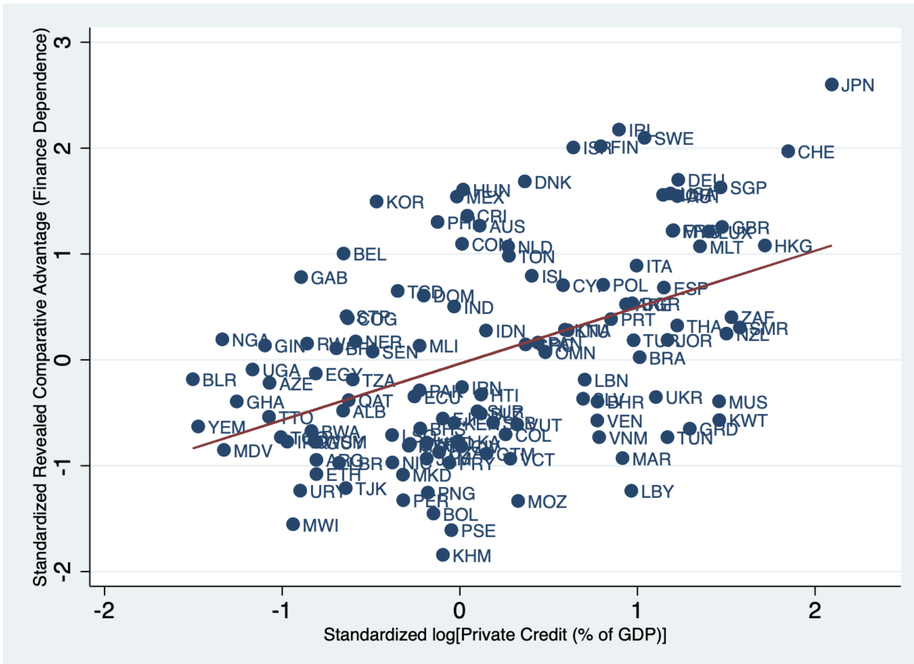
	external-finance dependence
log(Private Total Credit to GDP)	0.644***
	(0.102)
Observations	117
R-squared	0.258

Notes: Table 4 reports second-stage regression results examining the effect of financial development on comparative advantage in finance-dependent industries. The dependent variables are the country-specific revealed comparative advantage (RCA) coefficient estimated from first-stage regressions using bilateral trade flows in 2005. The column uses industry-level external finance dependence as in Rajan and Zingales (1998). Financial development is measured as the logarithm of private credit to GDP. Standard errors are clustered at the country level and reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

This result indicates that financial development is positively correlated with comparative advantage in finance-dependent sectors. In standardized terms, this means that a one standard deviation increase in financial development leads to a 0.644 standard deviation increase in comparative advantage in this sector. According to Costinot's (2009) Ricardian framework, this also implies that countries with high financial development will specialize in finance dependent industries. These results confirm previous findings from studies (see e.g. Manova, 2013; Leibovici, 2021; Ebrahimian and Firooz, 2023) show that financial development enables comparative advantage in finance dependent industries. Figure 1 plots this relationship. [7].

[7] The outliers Liberia (LBR) and Bhutan (BTN) are excluded for visibility

Figure 1: Standardized Revealed Comparative Advantage in Finance-Dependent Industries against Financial Development



Notes: This figure plots country-level comparative advantage in finance-dependent industries against the log of total private credit as % of GDP. The outliers Bhutan (BTN) and Liberia (LBR) are excluded for visibility. The slope is positive and statistically significant with a t-value of 6.33.

5 Finance Dependence, Innovation Dependence and Financial Development

We extend our baseline analysis by examining whether the effect of financial development on comparative advantage also applies to industries that rely heavily on innovation. Although previous research has established a link between financial systems and comparative advantage in finance dependent sectors (see e.g. Do and Levchenko, 2007; Manova, 2013), less is known about how financial development enables comparative advantage in innovation dependent industries. In this section, our aim is to address this gap.

5.1 Empirical Approach

To implement this extension, we first estimate innovation dependence following Sampson (2023). Next, we modify our specification in equation 2 to incorporate both external-finance dependence and innovation dependence. To estimate the Ricardian revealed comparative advantage of innovation and finance dependent industries, we follow Costinot's (2009) two-stage empirical approach and run the following regression:

$$\ln(x)^i_{\text{od}} = \alpha_{\text{od}} + \beta^i_{\text{d}} + \delta_o[\text{Fin Dep}]^i + \gamma_o[\text{ID}]^i + \varepsilon^i_{\text{od}} \tag{5}$$

In this specification, the indexes *i*, *o*, *d* represent industry, origin country, and destination country, respectively. The two terms, α_{od} and β^i_{d}, capture origin-destination and destination-industry fixed effects. The outcome variable $(x)^i_{\text{od}}$ measures trade flows from the origin country *o* to the destination country *d* in industry *i*. Following Rajan and Zingales (1998), $[\text{Fin Dep}]^i$ is the external finance dependence of an industry *i*, and $[\text{ID}]^i$ is the estimated innovation dependence, based on Sampson (2023). To run the regression specified in equation (5), we use Comtrade import flows for 165 exporters and 167 importers, as done by Ebrahimian and Firooz (2023), in 19 2-digit ISIC Rev. 4 manufacturing industries in 2005.

The coefficients of interest, δ_o and γ_o, quantify the cross-country comparative advantage in finance-dependent and innovation-dependent industries. To interpret these coefficients, we derive the following difference-in-differences expression:

$$\begin{aligned}\text{E}\left[\ln\left(\frac{x^{i_1}_{o_1 d}}{x^{i_2}_{o_1 d}}\right) - \ln\left(\frac{x^{i_1}_{o_2 d}}{x^{i_2}_{o_2 d}}\right)\right] &= (\delta_{o_1} - \delta_{o_2}) \cdot \left([\text{Fin Dep}]^{i_1} - [\text{Fin Dep}]^{i_2}\right) \\ &\quad + (\gamma_{o_1} - \gamma_{o_2}) \cdot \left([\text{ID}]^{i_1} - [\text{ID}]^{i_2}\right)\end{aligned} \tag{6}$$

This representation shows that countries with higher δ_o or γ_o will export relatively more in finance- and innovation dependent industries. The difference-in-differences approach helps mitigate concerns about endogeneity and reverse causality that typically arise in regressions of trade outcomes. To further address causality concerns, we use a 5- or 10-year lag of financial development in our robustness checks.

In the second-stage, we regress these coefficients on country-level financial development to test whether financial systems systematically shape comparative advantage in these two types of sectors. We run the following second-stage regressions:

$$\delta_o = \omega_1 + \phi_1 \cdot \log[\text{FinDev}]_o + \varepsilon_o, \tag{7}$$

$$\gamma_o = \omega_2 + \phi_2 \cdot \log[\text{FinDev}]_o + \varepsilon_o, \tag{8}$$

where δ_o and γ_o are the coefficients estimated from equation 5, reflecting country o's comparative advantage in finance-dependent and innovation-dependent industries respectively. $[\text{FinDev}]_o$ represents the financial development of country o, which is measured as the log of private credit over GDP. ω_1 and ω_2 are our coefficients of interest. A positive ω_i indicates that countries with higher financial development have a stronger revealed comparative advantage in finance dependent industries, and similarly, a positive ϕ_2 means that countries with higher financial development have stronger revealed comparative advantage in innovation dependent industries. [8]

This methodology exploits variation in exports across industries with differing reliance on external finance and innovation. By comparing these patterns across countries with different levels of financial development, we isolate the extent to which financial institutions shape comparative advantage. It also allows us to analyze the underlying correlation between finance and innovation dependent sectors, we compare the coefficients from equation (4) and (7). If Z is smaller than Y, we can conclude that without controlling for innovation dependence, a part of the effect is captured by external-finance dependence. Standard errors are clustered at the exporter (origin) level.

5.2 First Stage Regression

The result of our first stage regression confirms that both industry-level innovation dependence and external-finance dependence significantly affect international trade patterns. We observe substantial variation in the estimated revealed comparative advantage across countries. These findings align with our regression results, and prior research (Manova, 2013; Leibovici, 2021; Ebrahimian and Firooz, 2023; Sampson, 2023).

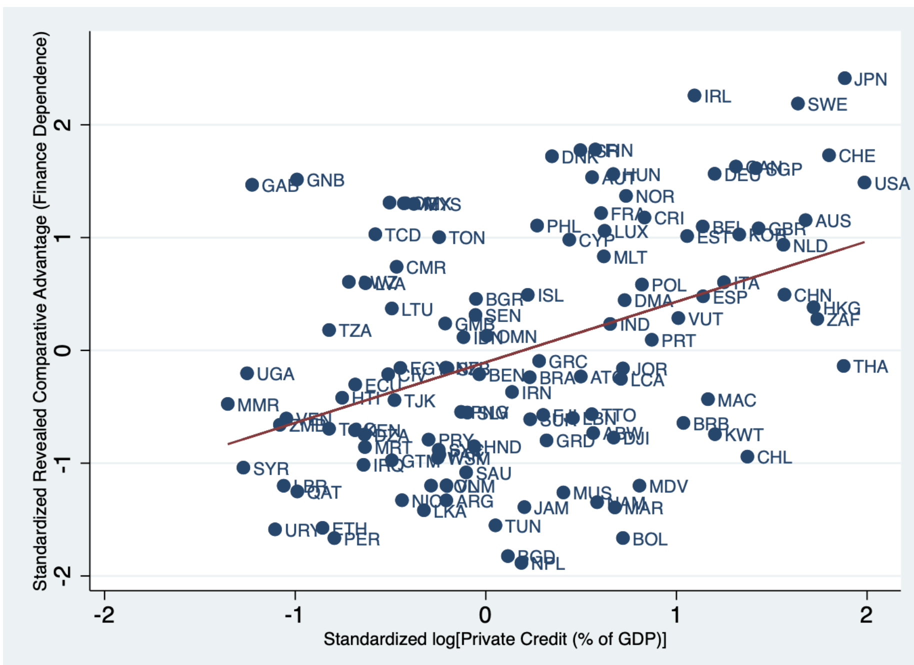
5.3 The Role of Financial Development on Comparative Advantage in Finance Dependent Industries

We run the second-stage regression and find that there is heterogeneity across countries in how financial development facilitates comparative advantage in both innovation and finance dependent industries. As shown in Table 5, countries with higher external finance dependence, based on the first stage regression, exhibit a statistically significant relationship with financial development, with a standardized coefficient of 0.536 (p-value < 0.001). This suggests that a one standard deviation increase in financial development is associated with a 0.536 standard deviation increase in comparative advantage of finance dependent industries.

[8] Standard errors are clustered at the exporter (origin) level. This accounts for correlated error terms within countries exporting across multiple industries. Clustering at this level ensures that our inference reflects the structure of the data and the source of comparative advantage.

While the R-squared value of 0.178, indicates that financial development explains a small share of the total variance in comparative advantage, the direction, significance and magnitude of the coefficients points to an economically meaningful relationship. This is consistent with prior studies on how financial development enables comparative advantage in financially dependent industries (see e.g. Manova, 2013; Leibovici, 2021; Ebrahimian and Firooz, 2023). Figure 2[9] visualizes this relationship by plotting the comparative advantage of finance dependence against the log of private credit over GDP. The upward-sloping trend shows the systematic association between financial development and the ability to specialize in finance dependent industries. Among countries with the highest observed financial development and financial dependency are Sweden, Japan, and Ireland, whilst countries that exhibit comparably low levels of financial dependency and financial development consist of Laos, Ethiopia, and Malawi.

Figure 2: Standardized Revealed Comparative Advantage of Finance-Dependent Industries Against Financial Development



Notes: This figure plots country-level comparative advantage in finance-dependent industries against the log of total private credit as % of GDP. The outliers Bhutan (BTN) and Liberia (LBR) are excluded for visibility. The slope is positive and statistically significant with a t-value of 5.01.

[9]The outliers Liberia (LBR) and Bhutan (BTN) are excluded for visibility.

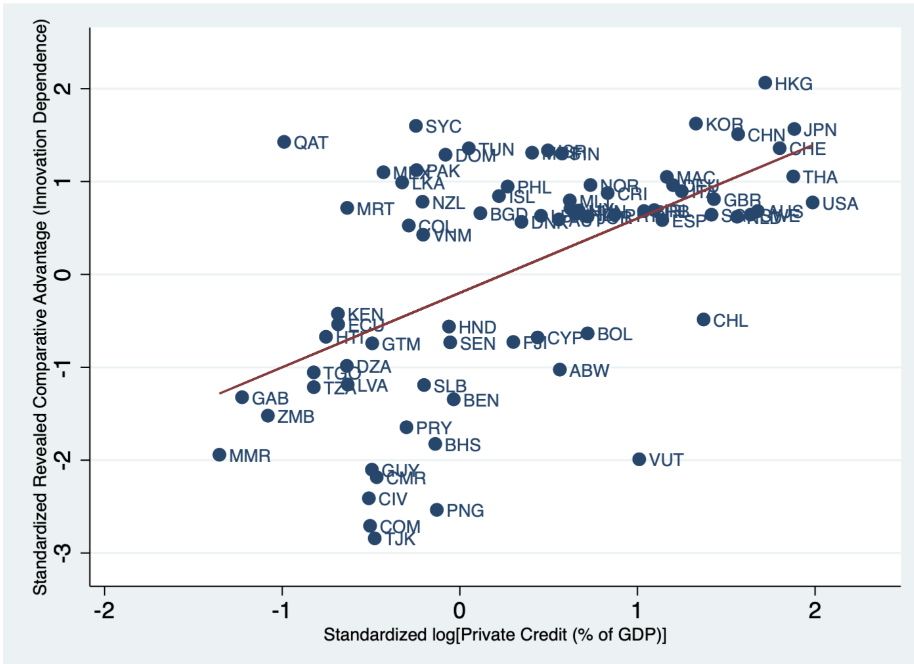
5.4 The Role of Financial Development on Comparative Advantage in Innovation Dependent Industries

We extend the analysis by considering innovation dependence. Column 2 in Table 5 shows that financial development is also a key enabler of comparative advantage in innovation dependent sectors. The regression yields a standardized coefficient of 0.801 (p-value < 0.001), indicating an even stronger association than in the case of finance dependence. We can interpret this as a one standard-deviation increase in financial development leads to a 0.801 standard deviation increase in comparative advantage in innovation dependent industries. The R-squared of 0.307 supports the idea that strong financial institutions are essential for converting innovation into comparative advantage

Financial development does not only support capital investment, it enables R&D activity through innovation driven export performance. This means that financial development is especially important for encouraging firms to invest in R&D. Because innovation often involves high risk and few tangible assets, firms need a larger fraction of equity financing, and thus strong financial systems to support these kinds of activities. Furthermore, following Costinot's (2009) framework of Ricardian comparative advantage, our result indicates that countries with better financial systems will specialize in innovation and R&D, and tend to export relatively more in industries with a stronger reliance on innovation. These results are plotted in Figure 2[10].

[10]The outliers Liberia (LBR) and Bhutan (BTN) are excluded for visibility.

Figure 3: Standardized Revealed Comparative Advantage of Innovation-Dependent Industries Against Financial Development



Notes: This figure plots country-level comparative advantage in innovation-dependent industries against the log of total private credit as % of GDP. The outliers Bhutan (BTN) and Liberia (LBR) are excluded for visibility. The slope is statistically significant with a t-value of 5.68.

From our regression, countries with high Total Private Credit/GDP such as Japan (JPN) and Hong Kong (HKG) also have high degrees of innovation dependence. Notably, several low-income countries with underdeveloped financial systems, such as Mozambique (MOZ), Papua New Guinea (PNG) and Tajikistan (TJK), exhibit a strongly negative comparative advantage in these industries, reinforcing the importance of domestic financial infrastructure in enabling knowledge-based trade.

We also observe a spread in the data among countries with similarly low levels of financial development. For example, Qatar and New Zealand exhibit a relatively high level of measured country-level innovation dependence, while countries such as the Comoros and Tajikistan are shown to have a significantly lower degree of innovation dependency, despite the slightly higher financial development than the formerly mentioned countries. Due to the large vertical spread of the data, innovation dependence is not entirely explained by financial development. This indicates that since financial development alone does not fully explain comparative advantage in innovation dependent industries, other institutional factors likely affect a country's ability to compete in R&D-based trade [11].

Furthermore, a wider horizontal spread of the standardized scatterplot can also be observed among countries with high levels of innovation dependence. Thus, our results suggest that while

[11] For example, Sampson (2023) found that &D efficiency positively correlates to a country's comparative advantage in R&D-based trade.

financial development is an important enabler for innovation dependent industries, other factors may also be key for their comparative advantage.

Findings are also consistent with the theoretical insights of Sampson (2023) who models cross-country differences in R&D efficiency as a central driver of income and wage dispersion. He shows that narrowing these innovation efficiency gaps substantially reduces economic inequality, suggesting that comparative advantage in innovation is a key determinant of national economic success. Financial development, by reducing capital constraints for intangible and high-risk investments, effectively narrows these innovation efficiency gaps and enables countries to compete in R&D-intensive sectors.

Table 5: The Impact of Financial Development on Comparative Advantage in Finance and Innovation Dependent Industries

	external-finance dependence	In Dep 3
log(Private Total Credit to GDP)	0.536***	0.801***
	(0.107)	(0.141)
Trade cost controls		Yes
Productivity level controls		Yes
Comparative advantage controls		Yes
Observations	118	75
R-squared	0.178	0.307

Notes: Table 5 reports second-stage regression results examining the effect of financial development on comparative advantage in finance- and innovation-dependent industries. The dependent variables are the country-specific revealed comparative advantage (RCA) coefficients estimated from first-stage regressions using bilateral trade flows in 2005. The left column uses industry-level external finance dependence as in Rajan and Zingales (1998), while the right column uses InDep 3, our preferred measure of innovation dependence constructed from R&D efficiency and including the full set of controls (Sampson, 2023). Financial development is measured as the logarithm of private credit to GDP. Standard errors are clustered at the country level and reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

5.5 Innovation Dependence as a Source for Finance Dependence

To analyze whether comparative advantage in finance dependent industries is driven by innovation dependence, we compare the normalized coefficients from regressing comparative advantage in finance dependent industries on financial development. When innovation dependence is incorporated into the regression, the coefficient on finance dependence drops from 0.644 to 0.536, which corresponds to a 16.77% decrease. This suggests that the comparative advantage of finance-dependent industries is, at least in part, driven by their reliance on innovation systems, rather than purely by capital market frictions.

This insight aligns with the financing logic by Brown et al. (2013), who argue that R&D investments are structurally incompatible with traditional debt financing due to their intangibility, uncertain returns, and limited collateral value. As a result, innovation dependent firms depend disproportionately on internal cash flow and access to equity markets. These financing constraints mean that industries with high innovation dependence exhibit high external finance dependence, not because of general capital needs, but because their R&D activity creates structural reliance on external, often equity-based funding. Furthermore, Brown et al. (2009) support their interpretation. They document that young, high-tech firms rely almost exclusively on internal cash flow and equity issuance to finance R&D, while mature firms display little sensitivity to financial variables. These results imply that it is not solely capital intensity that drives financial dependence, but the specific financing needs of innovation, particularly the need for risk-tolerant, equity-based capital structures. This also explains why financial development enables comparative advantage in innovation dependent industries since their funding is reliant on well-functioning equity systems.

This pattern refines, rather than contradicts, earlier findings in the literature. Rather than viewing finance and innovation dependence as parallel channels, we show that financial development supports comparative advantage in innovation dependent sectors, and that this innovation dependence is a key driver of what is traditionally captured by finance dependence measures. In this sense, financial development enables countries to convert R&D efforts into international trade flows, aligning with Sampson (2023), who models how cross-country differences in innovation efficiency generate income dispersion. Improved financial systems, by reducing frictions in high-risk, intangible investments, close these efficiency gaps, and enhance export performance in knowledge-based industries.

5.6 Robustness Tests

The results are robust to alternative measures of financial vulnerability, innovation dependence and financial development. A 5-year lag and 10-year lag is also applied when testing robustness for financial development. We only substitute one variable at a time when testing robustness.

We evaluate the robustness of financial dependency by replacing the main measure external-finance dependence with two separate proxies: asset intangibility and capital intensity (see section 3). Results can be found in Appendix C, Table 7. First, external finance dependence is replaced with our first proxy; industry-level asset intangibility. The coefficient is significantly larger than the coefficient estimated using external finance dependence. Furthermore, innovation dependence in this regression is also slightly higher, compared to our original regression. Intuition for such results can be connected to the facts that intangible assets largely consist of brand, reputation, R&D and knowledge-based assets (Manova, 2013). Thus, a large focus on innovation and development within firms may be largely correlated with intangible R&D-related asset creation, which explains a large correlation between innovation dependence and asset intangibility within industries.

Table 7, Column 2 presents second-stage regression results using capital intensity. A marginally larger level of effect of Capital Intensity, compared to external finance dependence. Compared to the regression using external finance dependence, the coefficient for Innovation dependence is slightly higher when using Capital Intensity as a proxy. Both coefficients are significant with a p-value < 0.001. This implies that when replacing external finance dependence with capital intensity, the effect of both innovation and finance dependence is shown to be slightly higher compared to the original measure, although not to a significant scale. Results for finance dependency are robust due to the close range of values produced from all proxies. All coefficients are positive and significant with the exception that asset intangibility is positive but insignificant.

Robustness for innovation dependence is also tested by replacing the main variable with proxies introduced in section 3. In Dep 2, produces a significantly larger effect of innovation dependence on country and industry-specific export levels, while the effect of external finance dependence on our dependent variable decreases significantly, compared to the regression using In Dep 3. Results for robustness tests with innovation dependence can be found in Table 8.

Similarly, In Dep 1 in Table 8, Column 1, produces a large coefficient of comparative advantage along with a smaller coefficient of comparative advantage of financial dependency, compared to our main regression. External finance dependence is significant at the 5% level. Thus, the significance of finance dependence increases when productivity level controls on the innovation dependence measure are removed. The significantly large coefficients for In Dep 2 and In Dep 1 can similarly indicate the remarkable effects of removing productivity level controls and comparative advantage controls from the regression. As the significance and effect of financial dependency decreases when controls are removed, potential productivity and comparative advantage aspects of the innovation variable can be attributed to, and also affect finance dependence. By contrast, the fourth proxy, denoted In Dep 4, exhibits a smaller effect on the dependent variable compared to the main measure. Both external finance dependence and R&D measures based on industry-level patent activity are significant at a 1% level. Patent activity instead reduces the relative effect of innovation dependence, and increases the effect of external finance dependence compared to the main regression.

All innovation proxies show positive and significant effects on international export-levels at the 1% significance level, when replacing the main measure in the second-stage regression. However external finance dependence is affected differently depending on the proxy used. In a general sense, robustness of innovation dependence can be concluded to have an acceptable level of reliability.

Robustness tests for financial development are executed through usage of Private Total Credit as a Percentage of GDP for 10 years previous to the original estimation period, and 10 years after the estimation period, thus in 1995 and 2015, following Ebrahimian and Firooz (2023). Furthermore, five-year lags and ten-year lags for financial credit to GDP are used as alternative proxies, in order to address reverse-causality concerns. Additional proxies for financial development are Level of Credit to GDP, the log of Financial System Deposit to GDP. Results for robustness tests for financial development can be found in Table 9. Among a majority of financial development proxies results show a statistically similar result to our main measure, with an exception of a few deviating variables. Financial development measured at the logarithm of Private Credit to GDP in 2015 demonstrate a significantly stronger explanatory effect. All results are statistically significant at a 1% level, and exhibit a positive relationship with both financial dependence and innovation dependence. Overall, this suggests that results produced with financial development are robust.

6 Conclusion

This paper investigates how country-level financial development enables comparative advantage in finance and innovation dependent industries. We also examine whether the comparative advantage observed in financially dependent sectors is partly driven by their underlying reliance on innovation.

Our analysis shows that finance dependence is a significant predictor of industry-level comparative advantage in international trade. Additionally, finance dependent industries are shown to benefit from financial development in terms of comparative advantage. Furthermore, we find that both finance dependence and innovation dependence significantly affect country and industry-level exports where finance dependent sectors are, to a smaller degree compared to innovation dependent sectors, positively enabled by the country-level financial development. Through the addition of innovation dependence in our regression, we demonstrate that parts of the observed impact of financial development on finance-dependent industries are driven by their reliance on innovation. Our findings show that RD-intensive sectors rely on external financing, making them sensitive to differences in financial development.

The findings are based on multiple data sources, such as the OECD STAN and ANBERD databases, the U.S. Compustat database, and bilateral trade data compiled by Ebrahimian and Firooz (2023) from Comtrade. We follow Sampson (2023) to estimate innovation dependence and rely on industry-level finance dependence data from Ebrahimian and Firooz (2023).

To estimate industry comparative advantage, we employ a two-stage regression framework based on Costinot (2009) and Ebrahimian and Firooz (2023). In the first stage, we regress bilateral trade flows on industry-level external-finance and innovation dependence, controlling for exporter-importer and importer-industry fixed effects. In the second-stage regression, we regress the resulting country-specific comparative advantage coefficients on financial development, measured primarily by the logarithm of private credit to GDP. This structure allows us to estimate the enabling effect of financial development on trade in financially and innovation-intensive sectors.

Our findings contribute to a deeper understanding of how financial development not only facilitates specialization in finance-dependent sectors, but also serves as an enabler for comparative advantage in innovation-intensive industries. We also contribute by finding that parts of the previously observed comparative advantage in finance dependent industries is driven by innovation dependence. Future research could build on this framework by investigates which components of financial development, such as equity financing or venture capital, most effectively support comparative advantage in innovation-dependent sectors.

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For this paper, we have used Chat GPT 4o for help with coding, formatting of tables in overleaf, and help with industry mapping.

Appendix

A. Sampson's (2023) Calibration of Innovation Dependence

To analyze how innovation shapes international trade patterns, we construct a measure of innovation dependence following the methodology developed by Sampson (2023). Innovation dependence is not directly observable, as it captures structural features such as knowledge spillovers and the responsiveness of productivity to technological advancements. Instead, we infer innovation dependence from observed trade patterns, industry-level R&D intensity, and R&D efficiency differences between countries.

Sampson (2023) shows that countries with higher average R&D intensity within industries have a higher R&D efficiency. The intuition is that countries with higher R&D efficiency have a lower capability threshold for firms to innovate. This leads to more firms performing and investing in R&D which in turn yields a higher observed R&D intensity.

This relationship can be used to estimate R&D efficiency, a measure that captures how effectively a country converts its investments in R&D into tangible technological progress and productivity improvements. Each country is characterized by a specific R&D efficiency parameter, calibrated by analyzing cross-country differences in R&D intensity within the same industries (Sampson, 2023). R&D intensity is then a function of R&D efficiency and industry characteristics. Countries exhibiting consistently high R&D intensity across industries are inferred to have more effective national innovation systems, indicating superior capabilities in translating innovation expenditures into productive outcomes.

This macro-level calibration is grounded in the micro-behavior of firms, where individual innovation capabilities and decisions collectively shape national R&D outcomes.

In Sampson's (2023) theoretical framework, firms are heterogeneous in their capability to perform R&D. Each firm draws a capability level from a distribution, and only firms with sufficiently high innovation capability engage in R&D. The threshold for innovation, and thus the share of innovative firms in a country, depends on R&D efficiency. These firm-level decisions aggregate into a country-industry measure of effective innovative capacity, denoted Ψ_o^i, which combines the capabilities of both innovators and adopters. This aggregated capability is a central input in calculating how reliant an industry is on innovation. In theory, innovation dependence can be expressed with the following formula:

$$[\text{ID}]^i = \frac{1+\kappa_i}{\gamma_i} + \left((1-\beta) - \frac{\alpha(1+\kappa_i)}{\gamma_i}\right) \times \frac{\partial \log \Psi_o^i}{\partial \log B_o}, \tag{9}$$

where κ_i is the degree of localization of knowledge spillovers, γ_i is the advantage of backwardness parameter, β and α are the returns to scale in production and R&D respectively, Ψ_o^i is the effective innovation capability of country o in industry i, and B_o is R&D efficiency of country o. Since many variables in this expression are theoretical and not directly observable (Sampson, 2023).

The aggregation of firm-level innovation outcomes into industry-level productivity implies that some industries are more reliant on innovation than others. This reliance is captured by the concept of innovation dependence, defined as the elasticity of industry productivity with respect to country-level R&D efficiency. It reflects how much an industry's performance improves as R&D becomes more effective and in industries with high innovation dependence, improvements in R&D lead to disproportionately larger gains in productivity. According to Sampson (2023), this elasticity is shaped by structural features of the industry. In particular, innovation dependence increases with the degree of knowledge spillovers that remain within national borders and with the returns to scale in production. Conversely, it decreases in industries where less productive firms can easily catch up, a mechanism referred to as the "advantage of backwardness." A higher value of $[\mathrm{ID}]^i$ implies that an industry's trade and productivity outcomes are more sensitive to national differences in R&D performance. Understanding the variation in innovation dependence across industries is crucial for linking differences in national innovation systems to patterns of international trade.

In Sampson's (2023) framework, differences in innovation dependence shape international trade patterns. Countries with higher R&D efficiency benefit more in industries where productivity is highly sensitive to innovation. This means that countries with higher R&D efficiency have a comparative advantage in innovation-dependent industries. As a result, a country's export performance across industries reflects the interaction between its R&D efficiency and the innovation dependence of different industries (Sampson, 2023). This relationship provides the basis for empirically estimating innovation dependence by examining how cross-country variation in R&D efficiency are correlated with bilateral trade flows.

To estimate innovation dependence empirically, we use a gravity-model-based regression approach using bilateral trade data (Sampson, 2023). Specifically, differences in R&D efficiency across countries are used to explain observed variations in trade flows, revealing how dependent different industries are on innovation for international competitiveness. The resulting coefficient from this regression represents our innovation dependence measure and quantifies the extent to which productivity in each industry improves as R&D efficiency increases. The following formula can be used:

$$\log\left(\frac{X^i_{od}}{X^i_{dd}}\right) - (\sigma-1)\log\left(\frac{w_d}{w_o}\right) = -(\sigma-1)\frac{[\mathrm{ID}]^i}{k}b_o - (\sigma-1)A^i_o + (\sigma-1)\tau^i_{od} + \varepsilon^i_{od}, \tag{10}$$

where X^i_{od} is exports of industry i from country o to country d and X^i_{dd} is exports in industry i from a country d to itself (i.e domestic sales in country d). The logarithm of the fraction on the left-hand side measures the ratio of bilateral exports from country o to domestic sales in country d in log terms. Here, we denote bilateral trade flows (or exports) with large X (in comparison to small x in our model (equation 5), which represents that the data comes from OECD database. w_o and w_d are wages in origin country o. σ is the elasticity of substitution, which measures how easily one good can be substituted for another in response to changes in relative price. We follow Sampson (2023) and set $(1-\sigma) = 6.53$. 6.53 is their preferred value of $(1-\sigma)$. $[\mathrm{ID}]^i$ is the innovation dependence of industry i, b_o is the log of R&D efficiency in the origin country o and the shape parameter k represents firm heterogeneity. A^i_o represents allocative efficiency and captures non-R&D-related productivity differences of industries i in country o. Including this measure allows us to control for the possibility that countries with high R&D efficiency might also have better and more efficient institutions, which could bias the estimate on innovation dependence. The term τ^i_{od} represents exporter-industry fixed effects and is included to capture the possibility that export costs vary by countries as argued by Waugh (2010). ε^i_{od} is the error term. According to Sampson (2023) τ^i_{od} is calculated from the following formula:

$$\tau^i_{od} = DIST^i_{od} + BORD^i_{od} + CLANG^i_{od} + FTA^i_{od} + (\delta^i_o)^2, \tag{11}$$

where $DIST^i_{od}$ is distance-based trade cost, $BORD^i_{od}$ is a border dummy that takes the value 1 if two trading partners share a common border. $CLANG^i_{od}$ is a common language dummy, FTA^i_{od} is a free trade agreement dummy and δ^i_{od} exporter-industry fixed effect.

When estimating innovation dependence in equation (10), the product of

$$\frac{[\text{ID}]^i}{k} b_o$$

is sufficient to quantify the impact on R&D efficiency. Consequently, there is no need to calibrate k separately.

For robustness, we estimate innovation dependence with 3 different sets of controls: trade cost, country and comparative advantage controls. We also estimate innovation dependence with patenting activity-based R&D efficiency using the full set of controls as a fourth proxy.

A.1 Alternative Calibration R&D Efficiency Using Patenting Activity

As an alternative to using R&D expenditure data, R&D efficiency can be calibrated using patenting intensity, following Sampson (2023). Patenting intensity for country o and industry i, denoted PAT^i_o, is defined as:

$$\text{PAT}^i_o = \frac{\text{Patents}^i_o}{\text{Value Added}^i_o} \tag{12}$$

where Patents^i_o are number of patents filed and Value Added^i_o is the value added from industry i in country o.

Sampson (2023) assumes unit elasticity between patenting and R&D expenditure ($\Lambda = 1$). Hence, patenting intensity is proportional to R&D intensity:

$$\text{PAT}^i_o = \Lambda^i_0 \times \text{R\&D Intensity}^i_o$$

where Λ^i_0 is an industry-specific constant that reflects differences in the propensity to patent across sectors. Under this assumption, patenting intensity and R&D intensity are interchangeable for the purpose of calibrating country-level R&D efficiency B_s.

B. Industry Mapping

The different raw datasets contains different industry classification systems. The mapping process involves linking categories from ISIC rev 2 to ISIC rev 4 based on economic activity. The two primary processes occur: 1) Disaggregation of broad ISIC Rev. 2 (three digit) industries into multiple ISIC Rev 4 categories (two digit), and 2) Reclassification of industries according to the modern definitions in ISIC Rev 4.

Sampson (2023) aggregated food manufacturing, beverages, and tobacco into a single category, 1012, (reflecting ISIC Rev 4 classification 10, 11, and 12). In Ebrahimian and Firooz (2023), food, beverages, and tobacco go under different classifications (311-2, 313, 314). We aggregate these by taking the industry average and map them to ISIC Rev 4 1012.

In the case of petroleum and coal products, ISIC Rev 2 treated petroleum refining (353) and petroleum and coal manufacturing (354) as separate industries. Sampson (2023) and ISIC rev 4 treated them under one single classification, 19 (Manufacture of coke and refined petroleum products). We merge financial dependence of 353 and 354 into a mean of the two and label them under ISIC Rev 4 as 19. Another distinction is made for transportation equipment. Under ISIC Rev. 2, all transport-related manufacturing was grouped into a single category (384). ISIC rev 4, however, splits this classification into two industries: manufacture of motor vehicles, trailers, and semi-trailers (29) and manufacture of other transport equipment (30). We group these together under a classification we call 2930, which corresponds to ISIC Rev 2. 384.

Lastly, the broader category of "other industries" (390) in ISIC Rev. 2 has been reorganized. Sampson (2023) merges ISIC Rev 4 classifications 31, 32, and 33 into a category called "Furniture and Other Manufacturing", classified as 3133. In Ebrahimian and Firooz (2023) and ISIC Rev. 2, "Other Industries" is classified as 390 (representing ISIC Rev.4 32 and 33). We merge ISIC Rev. 2 category 390 with 332 and map this new category to 3133. See Table 6 for the mapping key.

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Table 6: Industry Mapping Key from ISIC rev 2 to ISIC rev 4

Industry	**NACS**	**ISIC rev 4**	**IPC 4**	**ISIC rev 2**
Tobacco	Manufacture of food products; beverages and tobacco products	1012	D10T12	314
Footwear	Manufacture of wearing apparel	14	D14	324
Leather	Manufacture of leather and related products	15	D15	323
Beverages	Manufacture of food products; beverages and tobacco products	1012	D10T12	313

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Industry	**NACS**	**ISIC rev 4**	**IPC 4**	**ISIC rev 2**
Pottery	Manufacture of other non-metallic mineral products	23	D23	361
Food products	Manufacture of food products; beverages and tobacco products	1012	D10T12	311-2
Petroleum and coal products	Manufacture of coke and refined petroleum products	19	D19	354
Petroleum refineries	Manufacture of coke and refined petroleum products	19	D19	353
Nonmetal products	Manufacture of other non-metallic mineral products	23	D23	369
Printing and publishing	Printing and reproduction of recorded media	18	D18	342
Metal products	Manufacture of fabricated metal products, except machinery and equipment	25	D25	381
Industrial chemicals	Manufacture of chemicals and chemical products	20	D20	351
Iron and steel	Manufacture of basic metals	24	D24	371
Paper and products	Manufacture of paper and paper products	17	D17	341
Furniture	Manufacture of furniture	31	D31T33	332
Rubber and Plastic products	Manufacture of rubber and plastic products	22	D22	355-6
Transportation equipment	Manufacture of other transport equipment	30	D30	384
Transportation equipment	Manufacture of motor vehicles, trailers and semi-trailers	29	D29	384
Textile	Manufacture of textiles	13	D13	321
Nonferrous metal	Manufacture of basic metals	24	D24	372
Apparel	Manufacture of wearing apparel	14	D14	322

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Industry	NACS	ISIC rev 4	IPC 4	ISIC rev 2
Wood products	Manufacture of wood and of products of wood and cork, except furniture	16	D16	331
Glass	Manufacture of other non-metallic mineral products	23	D23	362
Other industries	Other manufacturing	32	D31T33	390
Other industries	Repair and installation of machinery and equipment	33	D31T33	390
Electric Machinery	Manufacture of electrical equipment	27	D27	383
Other chemicals	Manufacture of basic pharmaceutical products and pharmaceutical preparations	21	D21	352
Machinery	Manufacture of machinery and equipment n.e.c.	28	D28	382
Professional goods	Manufacture of computer, electronic and optical products	26	D26	385
	Furniture and other industries	3133	D31T33	

Notes: Table 6 presents the mapping key for merging the datasets with different industrial classification systems. The mapping involves matching industries based on economic activity, and averaging data for the industries that have multiple matches. Originally we have 20 ISIC rev. 4 industries, and 27 ISIC Rev 2. industries. After mapping, we are left with 19 ISIC rev 4. industries. See Ebrahimian and Firooz (2023) and Sampson (2023) for additional details.

C. Robustness Checks

Table 7: Robustness Checks: Alternative Proxies for Financial Dependence

	Asset Intangibility		**Capital Intensity**	
	Finance Dep.	Innovation Dep.	Finance Dep.	Innovation Dep.
log(Private Total Credit to GDP (%))	0.212	0.781***	0.761***	0.709***
	(0.163)	(0.130)	(0.170)	(0.160)
Observations	77	89	67	86
R-squared	0.022	0.295	0.236	0.190

Notes: Table 7 presents standardized coefficients from second-stage regression using alternative proxies for financial dependence: asset intangibility and capital intensity. These proxies are applied in equation (5) to estimate the comparative advantage of finance and innovation-dependent industries. The reported coefficients correspond to RCA estimates from equations (7) and (8). Innovation dependence is held constant using our baseline measure (In Dep 3). Standard errors are clustered at the industry-level and reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 8: Robustness Checks: Varying Proxy for Innovation Dependence

	InDep 1		**InDep 2**		**InDep 4**	
	External Dep.	InDep 1	External Dep.	InDep 2	External Dep.	InDep 4
log(Private Total Credit to GDP (%))	0.150	0.817***	0.277**	0.851***	0.497***	0.509***
	(0.110)	(0.152)	(0.120)	(0.151)	(0.093)	(0.140)
Trade cost controls		Yes		Yes		Yes
Productivity controls		No		Yes		Yes
Comparative advantage controls		No		No		Yes
Observations	122	64	115	66	131	89
R-squared	0.016	0.317	0.045	0.331	0.179	0.132

Notes: Table 8 reports robustness tests using alternative proxies for innovation dependence. Each column corresponds to a distinct proxy: InDep 1 and InDep 2 are based on R&D efficiency, while InDep 4 uses patent activity. These proxies are applied in equation (5) to estimate comparative advantage from equations (7) and (8). Financial dependence is held constant using the baseline external-finance dependence measure. Standard errors are clustered at the industry-level and reported in parentheses. ***, **, and * denote 1%, 5%, and 10% significance levels.

Table 9: Robustness Checks: Financial Development

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
external-finance dependence × financial development	0.576***	0.562***	0.489 ***	0.415***	0.284***	0.243*	0.545***
	(0.112)	(0.109)	(0.110)	(0.085)	(0.102)	(0.125)	(0.102)
innovation dependence ×							
financial development	0.734***	0.706***	0.764***	0.417***	0.689***	0.535***	0.564***
	(0.151)	(0.145)	(0.159)	(0.106)	(0.135)	(0.142)	(0145)

Notes: Table 9 presents robustness checks for the second-stage regression, using alternative proxies and time horizons for financial development. The first row reports the coefficient on the interaction between financial development and comparative advantage of external-finance dependent industries, while the second row shows the coefficient on the interaction between financial development and comparative advantage of innovation dependent (In Dep 3) industries. Column (1) shows the baseline results using the log of private credit to GDP. Columns (2) and (3) apply 5- and 10-year lags of financial development, respectively. Column (4) uses the level (rather than the log) of private credit to GDP. Column (5) uses financial system deposits to GDP as an alternative proxy. Columns (6) and (7) use financial development from 1995 and 2015, respectively. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. Bhutan (BTN) is excluded from the sample as an outlier.

C.1 Robustness using only Finance Dependence

Table 10: Robustness Checks: Financial Dependence Only

	(1)	(2)
log(Private Total Credit to GDP (%))	0.438***	0.916***
	(0.154)	(0.159)
Observations	75	67
R-squared	0.100	0.336

Notes: Table 10 presents robustness checks for the second-stage regression using alternative proxies for financial dependence, when only financial dependence is included in the first-stage regression. Columns (1) and (2) report results using asset intangibility and capital intensity, respectively. Standard errors are clustered at the industry level and reported in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 11: Robustness Checks: Financial Development and Financial Dependence only

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
external-finance dependence × financial development	0.648***	0.631***	0.553 ***	0.479***	0.450***	0.377***	0.673***
	(0.103)	(0.098)	(0.102)	(0.079)	(0.100)	(0.129)	(0.096)
Observations	125	123	119	130	129	103	123
R-squared	0.054	0.255	0.201	0.183	0.136	0.077	0.288

Notes: Table 11 presents robustness checks for the second-stage regression when only financial dependence is included in the first-stage regression. The table reports result using alternative proxies and time horizons for financial development. The first row reports the coefficient on the interaction between financial development and comparative advantage of external-finance dependent industries. Column (1) shows the baseline results using the log of private credit to GDP. Columns (2) and (3) apply 5- and 10-year lags of financial development, respectively. Column (4) uses the level (rather than the log) of private credit to GDP. Column (5) uses financial system deposits to GDP as an alternative proxy. Columns (6) and (7) use financial development from 1995 and 2015, respectively. Standard errors are clustered at the industry-level and presented in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.