Firm Credit, Technology Finance, and Income Growth in Aging Economies

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Abstract

Population aging changes the demand for firm upgrading and the demand for safe claims. This paper asks whether the income relation of aging depends on the sectoral allocation of private credit. The model separates credit that finances equipment, software, intangible capital, management systems, and organizational change from credit backed by household and real estate balance sheets. Aging raises the value of firm upgrading when labor becomes scarce, but it can also draw bank capacity toward private safe claims. The empirical design combines sectoral credit data, population cohorts, income outcomes, macro controls, crisis indicators, institutional measures, and globalisation controls for 1980 to 2014. Aging, credit shares, and their interactions are instrumented with predetermined cohort exposure and dynamic leave one out sectoral credit shift shares. The main five year instrumental variables estimate shows a positive aging by measured firm sector credit interaction for GDP per person growth. The estimate remains positive under overlapping window inference and after crisis, commodity, transition economy, human capital, absorptive capacity, and initial credit structure checks. The evidence supports a conditional claim. Aging has stronger income performance when bank balance sheets finance firm upgrading rather than private safe claims.

Keywords: population aging; sectoral credit allocation; firm upgrading; technology finance; income growth; safe assets; absorptive capacity.

JEL: E44; G21; J11; O16; O33; O47.

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1 Introduction

Population aging changes two margins that are often studied separately. The first margin is a firm margin. Older populations can raise the value of equipment, software, intangible capital, management systems, and organizational change that help firms operate with scarcer labor. The second margin is a balance sheet margin. Older households, pension funds, insurers, and financial intermediaries demand claims that are stable, liquid, and easy to pledge. These two margins meet inside the financial system. The effect of aging on future income can therefore depend on whether private credit finances firms that can upgrade, or whether it expands household, mortgage, real estate, and construction balance sheets.

This paper asks whether the future income relation of population aging depends on credit allocation. The question is narrower than a general theory of aging and growth. It asks whether a country with more measured credit directed toward firm sectors has a different aging income relation than a country where more credit is directed toward private safe claims. The distinction matters because aggregate credit depth can hide very different balance sheet allocations. Two countries can have similar demographics and similar private credit to GDP, while one directs credit toward firms that can adopt or reorganize technologies and the other directs credit toward collateral backed household claims.

The paper makes four contributions. First, it gives a simple framework that separates credit that can finance firm upgrading, firm collateral credit, private safe credit, public safe asset supply, and foreign safe asset access. The model implies that aging can raise private safe credit when domestic intermediaries absorb safe claim demand. It also implies that the aging by measured firm sector credit interaction should be positive for firm upgrading when measured sectoral credit captures finance for equipment, software, intangible capital, and organizational change. Private safe credit has an ambiguous sign because it can provide collateral services but can also absorb intermediary capacity. The framework also states a measurement condition under which a sectoral credit label can fail to capture technology finance in economies with weak absorptive capacity.

Second, the paper brings this framework to a country year panel from 1980 to 2014. The data combine sectoral credit, population cohorts, income and productivity outcomes, macro controls, capital account openness, public debt, technology diffusion measures, crisis indicators, and institutional measures. The baseline measured firm sector credit share uses credit to manufacturing, mining, transport, and communication. The private safe credit share uses household credit and real estate or

construction credit. The paper treats these variables as proxies, not as direct measures of loan purpose.

Third, the paper implements a symmetric IV design. Aging is instrumented with predetermined cohort exposure. Measured firm sector credit and private safe credit are instrumented with dynamic leave one out sectoral credit shift shares. The two interactions with aging are also instrumented. This symmetry is important because an interaction that contains an endogenous aging variable should not be treated as exogenous. The design addresses the main simultaneity concern in a conditional projection and makes the source of variation explicit. The paper then evaluates that source of variation through first stages, instrument anatomy, pretrend diagnostics, country trend diagnostics, crisis exclusions, sector exclusions, and controls for trade, commodity, human capital, institutional, absorptive capacity, initial credit structure, and globalisation channels.

Fourth, the paper opens the identifying variation rather than treating the shift share as a black box. The instrument is a ratio. A sector shock changes both the numerator and the denominator of the predicted credit share. The paper therefore derives a first order anatomy of the ratio instrument, reports which sectors drive the main five year IV sample, removes one sector at a time from the instrument, excludes major crisis windows, and adds controls for export exposure, oil rents, human capital, institutions, absorptive capacity, initial credit structure, and KOF globalisation measures. These diagnostics show that the income result is not a single crisis, commodity, transition, or open economy fact.

The main empirical result is an income result. In the five year IV specification, the aging by measured firm sector credit interaction is positive for GDP per person growth. TFP and technology diffusion estimates support the mechanism in high capacity samples and are reported as mechanism evidence. Longer horizons and aggregate mechanism decompositions are informative about scope, but the five year income projection is the central moment because it is where the instruments have the strongest support and where the theory maps most directly to aggregate data. The result is not driven only by the Asian crisis, the global financial crisis, or country years with banking crises. The paper therefore makes a focused claim: credit allocation conditions the income consequences of aging.

The development evidence is central for interpretation. The positive income relation is stronger in high income and institutionally stronger economies. In middle and low income economies, the measured firm sector credit interaction loads on a different mix of activities. That pattern is consistent with the model's measurement condition. The same sector label can correspond to technology finance in one economy

and to commodity credit, working capital, protected incumbents, or low capability firms in another.

The evidence is relevant for central bank and supervisory research because demographic pressure is not only a labor market or saving rate object. It also appears in the composition of bank balance sheets. The paper provides a state variable for analyzing aging economies: the allocation of private credit across firm, household, real estate, and construction balance sheets. The rest of the paper proceeds as follows. Section 2 places the paper in the literature. Section 3 develops the model and the measurement problem. Section 4 describes the data and empirical design. Section 5 reports the results and diagnostics. Section 6 concludes.

2 Related literature

The paper is related to research on demographics and technology. The idea that labor scarcity can raise incentives to automate or reorganize production appears in Zeira (1998), Autor et al. (2003), Graetz and Michaels (2018), Autor and Salomons (2018), and Acemoglu and Restrepo (2022). Evidence on aging and macroeconomic adjustment includes Bloom et al. (2010), Maestas et al. (2023), Kotschy and Bloom (2023), Rachel and Summers (2019), Auclert et al. (2021), and Auclert et al. (2025). The present paper adds a financial allocation margin. Aging can raise the demand for technologies that economize on labor, but the effect observed in income data depends on whether firms can finance the relevant upgrading.

A second related literature studies how demographics affect real rates, safe asset demand, debt, and macroeconomic adjustment. Carvalho et al. (2016) inspect the mechanisms through which demographics affect real interest rates, while Gagnon et al. (2021) connect demographic forces to the low real rate environment. Eggertsson et al. (2019) formalize secular stagnation as an equilibrium with a persistently low natural rate, and Carvalho et al. (2025) study demographic effects on real interest rates across countries and over time. Mian et al. (2021) show how household debt can lower aggregate demand and the natural rate. The International Monetary Fund also treats healthy aging and labor market adjustment as central macroeconomic issues in its discussion of the silver economy (International Monetary Fund, 2025). The present paper uses this literature to discipline the safe asset side of the model, but it focuses on the allocation of private credit rather than only on the aggregate interest rate.

The paper also connects to technology adoption and development. Comin and Hobijn (2004), Comin and Hobijn (2010), and Comin and Mestieri (2018) show that adoption lags are central for cross country income differences. Akerman et al.

(2015), Bloom and Van Reenen (2007), and Bloom et al. (2012) show that digital adoption and management practices depend on firm capabilities. Hsieh and Klenow (2009), Restuccia and Rogerson (2008), Buera et al. (2011), Midrigan and Xu (2014), and Moll (2014) show how distortions, financial frictions, institutional quality, and absorptive capacity can affect productivity and allocation. La Porta and Shleifer (2014) and Cirera et al. (2022) emphasize informality and capability constraints in developing economies. These papers motivate the interpretation of the development heterogeneity. A measured firm sector credit share is a proxy whose content depends on firm capability. It is more likely to capture technology finance when firms can absorb and implement new capital, software, and organizational practices.

A fourth literature studies safe assets and balance sheets. Caballero et al. (2017), Gorton et al. (2012), Gorton and Ordoñez (2014), and Krishnamurthy and Vissing-Jorgensen (2012) explain why safe claims are valuable and why their supply affects macroeconomic outcomes. Kiyotaki and Moore (1997) and Holmström and Tirole (1997) give foundations for collateral and pledgeability. Bernanke et al. (1999), Jordà et al. (2016), and Mian et al. (2017) show that credit composition and household balance sheets matter for macroeconomic dynamics. This paper puts safe claim production next to firm upgrading credit in the same demographic setting.

The paper is also related to finance and firm investment. Rajan and Zingales (1998) and Beck et al. (2000) connect finance to growth, while Beck et al. (2005) and Ayyagari et al. (2011) show that financial, legal, and governance constraints matter for firm growth and innovation in developing economies. Banerjee and Duflo (2014), Hall and Lerner (2010), Brown et al. (2009), Kerr and Nanda (2015), Akcigit and Kerr (2018), Brynjolfsson et al. (2002), Corrado et al. (2009), and Peters and Taylor (2017) show why innovation, intangible capital, and firm upgrading can have financing needs that differ from ordinary investment. The evidence in this paper is at the country year level. Loan purpose is therefore inferred from sectoral allocation, and the paper shows where the aggregate signal is strong and where it changes when sector labels are too coarse.

The empirical design is related to future outcome projections and shift share instruments. Jordà (2005) motivates projections of future outcomes on current states. The credit instrument follows the logic of Goldsmith-Pinkham et al. (2020), Borusyak et al. (2022), and Adão et al. (2019), which separate exposure shares from external shocks and emphasize the identifying content of the shock component. Altonji et al. (2005), Oster (2019), and Conley et al. (2012) motivate sensitivity analysis. Cameron et al. (2008), Cameron et al. (2011), MacKinnon and Webb (2017), and Djogbenou et al. (2019) motivate clustered, two way clustered, and wild clustered inference.

3 Model and empirical objects

Let A denote the old population share. Firms choose an upgrading intensity u. Upgrading includes technology adoption, software, equipment, management systems, reallocation toward more productive tasks, and organizational changes that allow firms to operate under demographic pressure. The financial system allocates balance sheet capacity across firm upgrading credit P, firm collateral credit C^F, and private safe credit C^H. Private safe credit is backed by household and real estate balance sheets. The economy also has a public safe asset margin S^G and access to foreign safe assets S^*.

The price of a safe claim is

$$q^S(A, S^G, S^*, C^H) = \bar{q} + \phi A - \chi_G S^G - \chi_* S^* - \chi_H C^H, \qquad \phi > 0, \quad \chi_G, \chi_*, \chi_H > 0. \tag{3.1}$$

The sign convention is in prices. Aging raises the value of safety. Public supply, foreign access, and private safe claim production reduce residual pressure on domestic private balance sheets. To link safe claim demand to credit reallocation, consider a local differentiable fixed point in which private safe credit satisfies the reduced form fixed point

$$C^H = \Psi(q^S(A, S^G, S^*, C^H), \mathcal{B}), \qquad \Psi_q > 0, \tag{3.2}$$

where $\mathcal{B}$ summarizes banking technology, regulation, and collateral institutions. The comparative static below is local to a stable fixed point.

Proposition 3.1 (Safe demand and private credit reallocation)**.** *Holding S^G, S^*, and $\mathcal{B}$ fixed, the fixed point in Equation (3.2) implies*

$$\frac{\partial C^H}{\partial A} = \frac{\Psi_q \phi}{1 + \Psi_q \chi_H} > 0. \tag{3.3}$$

The proof is in the Appendix.

This proposition is not a claim that all aging economies must expand household credit. It states the margin that should appear when domestic private balance sheets absorb safe claim demand. The first empirical table tests this reduced form reallocation margin.

The allocation of bank balance sheets is the margin that links safe claim demand to firm credit. Suppose an intermediary allocates a fixed local balance sheet capacity $\bar{B}$ between firm upgrading credit P and private safe credit C^H:

$$P + C^H = \bar{B}. \tag{3.4}$$

Let $R^P(A, P, \Omega)$ be the private marginal return to firm upgrading credit, and let the marginal return to private safe credit be $q^S(A, S^G, S^*, C^H) - m(C^H)$, where $m_C(C^H) > 0$ is an increasing marginal cost of using scarce intermediary capacity for that activity. An interior allocation satisfies

$$R^P(A, P, \Omega) = q^S(A, S^G, S^*, C^H) - m(C^H). \tag{3.5}$$

Proposition 3.2 (Intermediary allocation under aging). *Holding S^G, S^*, $\bar{B}$, and Ω fixed, suppose the local denominator satisfies*

$$\chi_H + m_C(C^H) - R^P_P(A, P, \Omega) > 0. \tag{3.6}$$

An interior allocation satisfying Equation (3.5) implies

$$\frac{\partial C^H}{\partial A} = \frac{\phi - R^P_A(A, P, \Omega)}{\chi_H + m_C(C^H) - R^P_P(A, P, \Omega)}, \qquad \frac{\partial P}{\partial A} = -\frac{\partial C^H}{\partial A}. \tag{3.7}$$

Aging shifts balance sheet capacity toward private safe credit when the aging response of safe claim demand exceeds the direct aging response of the private return to firm upgrading credit. The proof is in the Appendix.

Corollary 3.3 (Safe asset buffers and bank capacity). *Under the interior allocation in Proposition 3.2 and the denominator condition in Equation (3.6),*

$$\begin{aligned} \frac{\partial C^H}{\partial S^G} &= -\frac{\chi_G}{\chi_H + m_C(C^H) - R^P_P(A, P, \Omega)} < 0, \\ \frac{\partial C^H}{\partial S^*} &= -\frac{\chi_*}{\chi_H + m_C(C^H) - R^P_P(A, P, \Omega)} < 0. \end{aligned} \tag{3.8}$$

Because $P = \bar{B} - C^H$, public safe asset supply and access to foreign safe assets raise the balance sheet capacity left for firm upgrading credit. The proof is in the Appendix.

This proposition and Corollary 3.3 give a bank side reason for the credit reallocation fact. Aging can raise the value of firm upgrading and still shift observed credit away from firms if the private safe claim margin is more attractive to intermediaries. Public safe assets and foreign safe asset access matter because they can relax the domestic balance sheet pressure created by demographic demand for safety.

The firm upgrading problem is

$$\max_{u \geq 0} \left[\lambda(A)\Gamma(P + \theta C^F, \Omega) + \zeta(A)J(C^H, \Omega) - \mu(A)H(C^H, \Omega) - q^I\right] u - \frac{\kappa}{2}u^2, \tag{3.9}$$

where $\kappa > 0$. The term q^I is the user cost of financing the upgrading investment. It is distinct from the safe claim price q^S. The function λ captures the value of upgrading

when labor becomes scarce. The function Γ maps firm upgrading credit and firm collateral into upgrading capacity. The function J captures collateral reuse services of private safe credit, while H captures balance sheet absorption. The parameter vector Ω summarizes absorptive capacity, including management, contract enforcement, human capital, and the ability to use new technologies. The maintained conditions are $\lambda'(A) > 0, \Gamma_1 > 0, J_1 \geq 0, H_1 \geq 0, \zeta'(A) \geq 0$, and $\mu'(A) \geq 0$. For interior choices,

$$u^*(A, P, C^F, C^H, \Omega) = \frac{\lambda(A)\Gamma(P + \theta C^F, \Omega) + \zeta(A)J(C^H, \Omega) - \mu(A)H(C^H, \Omega) - q^I}{\kappa}. \tag{3.10}$$

Proposition 3.4 (Credit direction and firm upgrading). *At an interior choice, firm upgrading credit raises the marginal relation between aging and firm upgrading:*

$$\frac{\partial^2 u^*}{\partial A \, \partial P} = \frac{\lambda'(A)\Gamma_1(P + \theta C^F, \Omega)}{\kappa} > 0. \tag{3.11}$$

Firm collateral credit has the same sign when $\theta > 0$. The private safe credit cross partial equals

$$\frac{\partial^2 u^*}{\partial A \, \partial C^H} = \frac{\zeta'(A)J_1(C^H, \Omega) - \mu'(A)H_1(C^H, \Omega)}{\kappa}. \tag{3.12}$$

It is negative when balance sheet absorption dominates collateral reuse. The proof is in the Appendix.

The object observed most robustly in the IV design is income growth. Let future GDP per person growth satisfy

$$g^y_{i,t,h} = \rho_h u_{it} + \xi^y_{i,t,h}, \qquad \rho_h > 0, \tag{3.13}$$

where $g^y_{i,t,h}$ is the annualized growth rate from t to $t + h$. Aggregate TFP growth is a narrower and noisier object:

$$g^a_{i,t,h} = \tau_h u_{it} + \xi^a_{i,t,h}. \tag{3.14}$$

The coefficient τ_h can be positive, while measured aggregate TFP also contains utilization, terms of trade, factor measurement, sectoral composition, and adoption timing components. A strong income relation together with a TFP mechanism table is therefore consistent with the model. Aggregate TFP is treated as one mechanism outcome rather than as the only observable channel.

Proposition 3.5 (Income mapping). *If Equation (3.13) is locally valid and the residual component is mean independent of the residualized aging by firm sector credit interaction, then the projected interaction between aging and firm sector credit in future GDP per person growth inherits the positive sign in Equation (3.11). The same sign is expected in TFP only when the measured TFP outcome loads cleanly on firm upgrading. The proof is in the Appendix.*

The measured firm sector credit share can be a noisy proxy for technology finance. Let a measured interaction Z_M mix true technology finance Z_T and nontechnology firm credit Z_N:

$$Z_M = \pi(\Omega) Z_T + [1 - \pi(\Omega)] Z_N, \tag{3.15}$$

with $\pi'(\Omega) > 0$. Suppose the latent components have positive variances, are orthogonal after the maintained controls, and the outcome slopes satisfy $b_T > 0$ for true technology finance and $b_N(\Omega) \leq 0$ for the nontechnology component.

Proposition 3.6 (Measurement and absorptive capacity)**.** *Under orthogonality of the two latent components, the measured firm sector credit interaction is positive if and only if*

$$\pi(\Omega) > \frac{-b_N(\Omega) \operatorname{Var}(Z_N)}{b_T \operatorname{Var}(Z_T) - b_N(\Omega) \operatorname{Var}(Z_N)}. \tag{3.16}$$

Low absorptive capacity can make the measured interaction negative even when true technology finance has a positive aging interaction. The proof is in the Appendix.

Figure 1 illustrates the threshold result under a normalized parametrization.

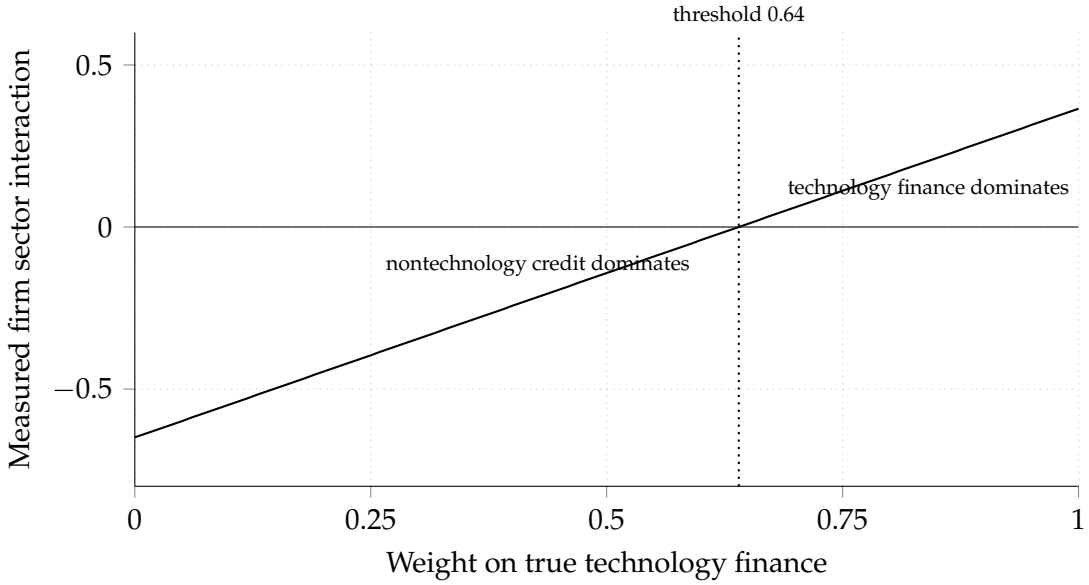


Figure 1: Measurement threshold. The horizontal axis is the share of the measured firm sector credit interaction that loads on true technology finance. The line shows the coefficient implied by Proposition 3.6 under a normalized parametrization.

The model gives three empirical objects. The first is a credit reallocation moment: aging is associated with a shift toward private safe claims when domestic balance sheets absorb safe demand. The second is the income interaction: the aging by firm sector credit interaction is positive for future income when firm sector credit

captures firm upgrading finance. The third is a measurement diagnostic: the same measured interaction can change sign in environments where the firm sector label contains commodity credit, working capital, or lending to firms without the capacity to implement new technology.

4 Data and econometric design

The analysis combines sectoral credit data from Müller and Verner (2024), population data from United Nations, Department of Economic and Social Affairs, Population Division (2024), productivity and income data from Feenstra et al. (2015); Groningen Growth and Development Centre (2025), diffusion variables from World Bank (2025), macro controls from International Monetary Fund (2026b), public debt data from International Monetary Fund (2026a), macro history controls from Müller et al. (2025), institutional variables from Teorell et al. (2026), capital account openness from Chinn and Ito (2006), and KOF globalisation measures from Gygli et al. (2019). The base years are 1980 to 2014 because sectoral credit data bind the endpoint. Future outcomes can use later information because they are measured as forward changes.

The old population share is the population aged 65 and over divided by total population. The baseline measured firm sector credit share is credit to manufacturing, mining, transportation, and communications as a share of total private credit. The available credit taxonomy combines manufacturing with mining and quarrying, so the paper cannot separate mining from manufacturing inside the main firm sector cell. The leave one sector diagnostics therefore remove the combined manufacturing, mining, and quarrying cell rather than mining alone. The private safe credit share is household credit plus real estate and construction credit as a share of total private credit. The institutional capacity measure averages standardized rule of law, regulatory quality, government effectiveness, and control of corruption from the Quality of Government file, and then standardizes the average in the analysis sample.

The main outcome is five year annualized GDP per person growth. TFP growth is retained as a mechanism outcome, not as the main claim. Internet, broadband, mobile diffusion, and technology payments are auxiliary outcomes because they mix firm adoption, household access, infrastructure, regulation, and saturation.

The baseline projection is

$$\Delta_h Y_{i,t+h} = \beta_{AP}(A_{it}P_{it}) + \beta_{AH}(A_{it}H_{it}) + \delta_A A_{it} + \delta_P P_{it} + \delta_H H_{it} + X_{it}'\gamma + \alpha_i + \tau_t + \varepsilon_{i,t+h}. \tag{4.1}$$

Here A, P, and H are standardized old population, measured firm sector credit, and private safe credit measures. Controls include lagged income per person, trade

openness, investment over GDP, and public debt over GDP. All regressions include country and year effects. Standard errors are clustered by country unless otherwise stated. A natural unit table translates the main interaction into a one percentage point increase in the old share combined with a ten percentage point increase in the relevant credit share.

The projection is followed by an IV design because credit allocation can respond to expected productivity, global sectoral opportunities, pension reforms, housing regulation, banking regulation, and capital flows. Current aging is instrumented with predetermined cohort exposure,

$$Z_{it}^{A} = S_{i,t-15}^{50+}, \tag{4.2}$$

where $S_{i,t-15}^{50+}$ is the share of the population aged 50 and over fifteen years earlier. These cohorts predict the old population share through demographic transition. The empirical design then asks whether the same predetermined cohort exposure has predictive content for future income only through the instrumented aging and credit allocation variables, after the included fixed effects and controls. Pretrend, past growth, country trend, and channel diagnostics are reported to discipline that assumption.

The credit instruments are dynamic sectoral shift shares. Let $s_{ik,t-L}$ denote the lagged share of country i's private credit in sector k, and let

$$g_{-i,k,t} = \frac{\bar{s}_{-i,k,t}}{\bar{s}_{-i,k,t-L}} \tag{4.3}$$

be the leave one out global change in sector k's credit share. The predicted firm sector credit share is

$$Z_{it}^{P} = \frac{\sum_{k \in \mathcal{P}} s_{ik,t-L} g_{-i,k,t}}{\sum_{k} s_{ik,t-L} g_{-i,k,t}}, \tag{4.4}$$

where $\mathcal{P}$ contains manufacturing, mining, transport, and communication. The predicted private safe credit share is

$$Z_{it}^{H} = \frac{\sum_{k \in \mathcal{H}} s_{ik,t-L} g_{-i,k,t}}{\sum_{k} s_{ik,t-L} g_{-i,k,t}}, \tag{4.5}$$

where $\mathcal{H}$ contains household credit and real estate and construction credit. The main estimates use $L = 5$.

Because Z_{it}^{P} is a ratio, a sector shock changes both the numerator and the denominator. Let

$$\omega_{ik,t} = \frac{s_{ik,t-L} g_{-i,k,t}}{\sum_{j} s_{ij,t-L} g_{-i,j,t}}, \tag{4.6}$$

and let $\ell_{-i,k,t} = \log g_{-i,k,t}$.

Proposition 4.1 (Ratio shift share anatomy)**.** *For the measured firm sector credit instrument in Equation (4.4),*

$$\frac{\partial Z_{it}^{P}}{\partial \ell_{-i,k,t}} = \omega_{ik,t} \left(\mathbb{1}\{k \in \mathcal{P}\} - Z_{it}^{P} \right). \tag{4.7}$$

A shock to a firm sector raises the predicted firm sector share in proportion to its denominator weight and the gap between one and the current predicted share. A shock to a nonfirm sector lowers the predicted firm sector share through the denominator. The proof is in the Appendix.

The ratio form is important. The instruments are predicted shares, not raw sectoral shocks. For that reason, the paper reports an anatomy of the numerator and denominator of the shift share variables. This diagnostic follows the concern in Goldsmith-Pinkham et al. (2020), Borusyak et al. (2022), and Adão et al. (2019): one must know whether the design is driven by exposure shares, by a small set of sectors, or by shocks that have their own macroeconomic content. The anatomy table reports what variation the IV uses and separates exposure shares from external sectoral shifts.

The preferred IV specification treats A_{it}, P_{it}, H_{it}, $A_{it}P_{it}$, and $A_{it}H_{it}$ as endogenous. The excluded instruments are Z_{it}^{A}, Z_{it}^{P}, Z_{it}^{H}, $Z_{it}^{A}Z_{it}^{P}$, and $Z_{it}^{A}Z_{it}^{H}$. This symmetric treatment matters because an interaction that contains an endogenous aging variable should not be treated as exogenous, and because private safe credit is itself a credit allocation margin.

The baseline system is exactly identified. The paper therefore uses an augmented cohort specification with a second predetermined cohort predictor to report overidentifying diagnostics alongside the preferred exactly identified estimates. The identifying assumption is evaluated through first stages, instrument anatomy, reduced forms, pretrend diagnostics, country trend diagnostics, crisis exclusions, sector exclusions, controls for external demand, commodity exposure, human capital, institutions, absorptive capacity, KOF globalisation measures, and controls for initial sectoral credit structure.

The shift share design has two distinct sources of identifying content: lagged domestic exposure shares and external sectoral credit shocks. This distinction matters because exposure shares can be correlated with persistent industrial structure and global shocks can be correlated with commodity prices, technology waves, or external demand. The leave one out construction removes the mechanical domestic contribution to each shock, but it does not by itself remove common sectoral shocks. The identifying assumption is therefore conditional: after country effects, year effects, controls, and the included endogenous variables, the external sectoral credit reallocations should affect future income only through the instrumented domestic credit composition variables.

The paper reports the reduced form for the excluded firm sector interaction instrument, the first stages for each endogenous variable, ordinary least squares on the same IV samples, an internal lag diagnostic, a country trend first stage diagnostic, and sensitivity checks based on horizons, alternative aging measures, country trends, common samples, real rates, capital account openness, public debt, outliers, wild clustered inference, two way clustered inference, proportional selection, commodity exposure, transition economies, imperfect exclusion, and a reduced form pretrend diagnostic.

5 Results

Table 1: Aging and the direction of credit

	Firm credit share	Household credit share	Private safe credit share	Firm sector credit share	Real estate and construction share
Old share, one standard deviation	-9.504***	9.504***	5.670**	-2.315	-2.234
	(3.377)	(3.377)	(2.780)	(2.507)	(1.415)
Observations	2253	2253	1768	1693	1857
Countries	108	108	89	87	91

Notes: The dependent variables are shares of total private credit. Coefficients are reported in percentage points. Each column includes country and year effects, lagged income per person, trade openness, investment over GDP, and public debt over GDP. Standard errors clustered by country are in parentheses.

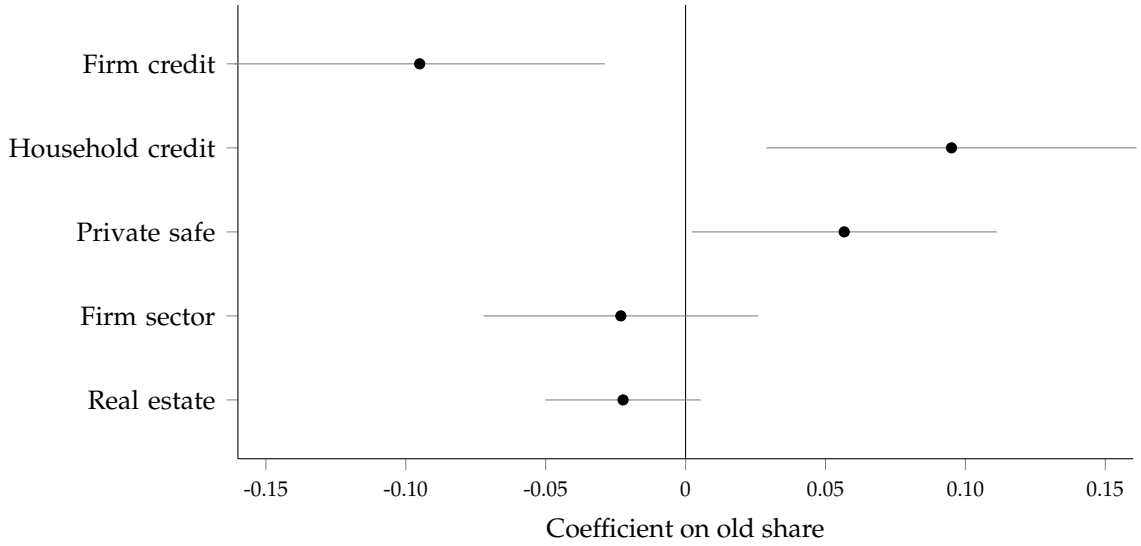


Figure 2: Aging and credit direction. Points are coefficients from country and year fixed effect regressions of credit shares on the standardized old population share. Lines are 95 percent confidence intervals with standard errors clustered by country.

Table 1 and Figure 2 report the first empirical fact. Aging is associated with a shift away from firm credit and toward household credit. A one standard deviation increase in the old share is associated with a 9.5 percentage point lower firm credit share and a 9.5 percentage point higher household credit share. The private safe credit share rises by 5.7 percentage points. The coefficient on the narrower firm upgrading category is smaller in this descriptive regression, so the robust descriptive margin is the change in the firm versus household split. This fact matters for the model because aging changes the composition of credit, not only the level of saving or the level of aggregate credit.

The Appendix repeats the credit direction exercise using the predetermined cohort instrument for aging. The sign pattern is the same. The cohort instrument predicts lower firm credit, higher household credit, and higher private safe credit. This evidence supports the balance sheet mechanism in the model: demographic pressure is visible in the allocation of domestic private credit.

Table 2: Instrumental variables estimates.

	TFP 5 year	TFP 10 year	GDP pc 5 year	GDP pc 10 year
Aging × firm sector credit	0.506	-8.489	1.957**	-0.725
	(0.476)	(44.831)	(0.876)	(4.291)
Observations	1210	603	1369	635
Countries	67	47	83	54
Minimum first stage F	62.5	28.2	49.0	33.2

Notes: The endogenous variables are the old population share, firm sector credit share, private safe credit share, and the two interactions with aging. The excluded instruments are predetermined cohort exposure, the dynamic leave one out sectoral credit shift shares for firm sector credit and private safe credit, and the corresponding interactions with cohort exposure. All variables in the interactions are standardized. All specifications include country effects, year effects, lagged income per person, trade openness, investment over GDP, and public debt over GDP. Standard errors clustered by country are in parentheses. *** p< 0.01, ** p< 0.05, * p< 0.10.

Table 3: First stage diagnostics for the excluded instruments.

Outcome sample	Old share	Firm sector share	Private safe share	Aging times firm sector	Aging times safe
TFP, 5 year	1195.6	68.7	62.5	310.6	278.0
TFP, 10 year	518.2	28.2	50.4	83.8	111.7
GDP per person, 5 year	1292.2	69.3	49.0	336.7	313.2
GDP per person, 10 year	543.4	33.2	46.8	86.6	116.1

Notes: Entries report partial first stage F statistics after country effects, year effects, baseline controls, and any included exogenous variables. The table reports the symmetric specification in which the private safe credit share and its aging interaction are treated as endogenous together with firm sector credit and aging.

Table 2 reports the symmetric IV estimates. Aging, measured firm sector credit,

private safe credit, and both interactions with aging are treated as endogenous. Current aging is instrumented with predetermined cohort exposure. Credit allocation is instrumented with dynamic leave one out sectoral credit shift shares. The two interactions are instrumented with the corresponding interactions between the excluded instruments. The main estimate is the five year GDP per person result. The coefficient on aging times measured firm sector credit is 1.957 with a country clustered standard error of 0.876. The sign is positive and the p value is 0.028. The same coefficient is positive for five year TFP, equal to 0.506, but the standard error is 0.476. The paper therefore treats the five year income estimate as the central empirical result and the TFP estimate as mechanism evidence.

Table 3 shows that the five year samples have strong excluded variation for the endogenous variables. In the GDP per person sample, the minimum first stage statistic among the five endogenous regressors is 49.0. In the TFP sample, the corresponding statistic is 62.5. The ten year samples are smaller and less informative. The Appendix reports coefficient first stages for the interaction instruments on the exact second stage samples. The excluded interaction instrument for aging times firm sector credit has a coefficient of 0.746 in the five year GDP per person sample and 0.779 in the five year TFP sample, with country clustered p values below one percent in both cases. These first stages address the mechanical concern that the interacted endogenous regressor is not predicted on the estimating sample.

The next set of results, reported in the Appendix, evaluates inference and the source of variation. A within country HAC correction for overlapping forward growth windows leaves the five year GDP per person coefficient at 1.957 and gives a standard error of 0.681. An overidentified cohort specification adds a second predetermined cohort predictor. The five year GDP per person coefficient remains positive at 1.163, the first stages remain above conventional weak instrument thresholds, and the Hansen diagnostic has a p value of 0.111. These exercises are not used to replace the baseline. They show that the central estimate is not produced by a single conventional standard error calculation or by a single cohort predictor.

The dynamic shift share instrument is also decomposed in the Appendix. In the five year GDP per person IV sample, household credit is the largest lagged exposure, and manufacturing and mining account for most of the firm sector numerator. Manufacturing, mining, and quarrying account for 39.7 percent of the absolute influence measure. Household credit accounts for 18.5 percent, trade for 11.0 percent, other credit for 10.7 percent, transport and communication for 9.8 percent, real estate and construction for 6.6 percent, and agriculture for 3.7 percent. This decomposition is important because the instrument is a ratio. A sectoral shock changes both the

numerator and the denominator of the predicted credit share. The Appendix derives this anatomy formally and shows which sectors provide the identifying movement.

The reduced form of the excluded firm sector interaction instrument is positive for the main income outcome. It is 0.814 for five year GDP per person growth and 0.529 for ten year GDP per person growth. The corresponding TFP reduced forms are also positive. The auxiliary technology outcomes are used as mechanism evidence. This is consistent with the model. The central prediction is about the income effect of aging when the financial system directs more credit toward sectors that can finance upgrading. The firm technology channel is interpreted through the model and the pattern across outcomes, not through a single observed technology variable.

The mechanism table in the Appendix separates GDP per person growth into related aggregate outcomes. The aging by firm sector credit interaction is positive and precise for five year GDP per person growth. TFP, investment, working age population, and current account outcomes are reported as mechanism diagnostics. The result supports a conditional income relation, while the scale tables show that the implied effect is economically meaningful in the part of the sample where the model says the sectoral credit proxy is most informative.

The horizon and measurement checks also appear in the Appendix. The five year GDP per person estimate is the central result because the sample and first stages are strongest at that horizon. The ten year symmetric IV estimates are reported to show how the design behaves over a longer window. Alternative aging measures preserve the basic message for income, and the broader technology table shows that ordinary least squares interactions are positive for TFP and GDP per person. The measurement validation table shows that measured firm sector credit is strongly correlated with tradable credit and only loosely related to nontradable credit, while private safe credit is closely related to household credit. These checks support the interpretation of the credit categories as broad allocation measures.

The development split is central for economic interpretation. In high income economies, the aging by measured firm sector credit interaction is strong for GDP per person growth and positive for TFP. In middle and low income economies, the TFP interaction carries a different magnitude. The country list and the institutional interaction table show that this pattern is aligned with absorptive capacity. In the governance covered sample, the triple interaction between aging, firm sector credit, and institutional capacity is positive for GDP per person and TFP. The interpretation is not that institutions are separately identified as a causal treatment. The interpretation is that the sectoral credit label carries more technology content when the economy has the capabilities needed to turn firm credit into upgrading.

The exclusion and channel checks support the main five year income result. Adding export exposure, oil rents, human capital, absorptive capacity, institutions, and a broad set of macro controls keeps the GDP per person coefficient positive. Human capital and absorptive capacity reduce the coefficient in smaller samples, but the sign remains positive and the estimate remains economically meaningful. Excluding transition economies and excluding major crisis windows also leaves the GDP per person interaction positive. Removing the Asian crisis years and the global financial crisis years gives coefficients close to the baseline. Dropping country years with banking crises gives a coefficient of 2.066 with a standard error of 0.982. These exercises make clear that the result is not a single crisis, commodity, or transition economy fact.

The initial sectoral structure and leave one sector out checks address a more specific concern about the shift share design. Controlling for initial household, real estate, construction, and firm sector credit shares keeps the five year GDP per person coefficient positive at 1.971. Removing one sector at a time from the instrument leaves the income result positive across all exclusions. The KOF globalisation checks also leave the five year GDP per person coefficient between 1.93 and 1.97, with first stage statistics above 41. These results support the view that the identifying variation is not only openness, financial globalisation, or one dominant sectoral component.

The model implies that private safe credit is a net object. It can provide collateral services, but it can also absorb balance sheet capacity. The Appendix shows that this ambiguity is visible in the data. Replacing the aggregate private safe measure with real estate and construction credit gives a negative interaction for GDP per person. Replacing it with household credit gives a smaller GDP interaction and a negative TFP interaction. This pattern is consistent with the model's distinction between collateral services and balance sheet absorption.

The pretrend diagnostics define the scope of the empirical claim. The excluded firm sector interaction instrument predicts past GDP per person growth in a five year placebo window, so the past growth control specification adds realized outcome growth ending at the base year to the symmetric IV design. The GDP per person interaction remains positive when the specification conditions on past three year, five year, or ten year GDP per person growth, with coefficients between 1.688 and 2.058. The country trend specification is also reported as a demanding diagnostic. The main design therefore uses both past growth controls and trend diagnostics to show the variation behind the five year income moment.

Taken together, the results support three conclusions. First, aging is associated with a reallocation of private credit toward household and private safe balance sheets.

Second, the income relation of aging is more favorable when more measured credit is directed toward firm sectors that can finance upgrading. Third, the aggregate data identify this as a conditional income result, with mechanism evidence from TFP and related outcomes, rather than as a direct loan level observation of technology adoption.

6 Conclusion

This paper asks whether the future income relation of population aging depends on credit allocation. The main five year IV design answers yes. When aging, measured firm sector credit, private safe credit, and both interactions are instrumented with predetermined cohort exposure and dynamic leave one out sectoral credit shift shares, the interaction between aging and measured firm sector credit is positive for GDP per person growth. The result remains positive under within country HAC inference for overlapping forward windows and after crisis, commodity, transition economy, initial credit structure, human capital, absorptive capacity, open economy, and globalisation checks.

The credit reallocation evidence explains why this conditional result is plausible. Aging raises safe claim demand and is associated with a shift of private credit away from firms and toward household and private safe balance sheets. The model shows that this reallocation can coexist with a higher value of firm upgrading. The sign observed in income data then depends on whether the financial system directs marginal credit toward sectors that can finance equipment, software, intangible capital, management systems, and organizational change, or toward private safe claims that absorb intermediary capacity.

The empirical claim is focused. The central identified moment is the five year GDP per person interaction. TFP, technology diffusion, and mechanism tables are reported as supporting evidence that helps interpret the aggregate income pattern. This is consistent with the measurement problem developed in the model. Sectoral credit data are broad allocation measures, not loan purpose data. The evidence is strongest where the model predicts the proxy to be most informative, namely in economies with higher income and stronger absorptive capacity.

For central bank and supervisory research, the result points to a measurement problem in demographic macro financial analysis. Aggregate private credit to GDP is not enough to describe the relevant balance sheet state. Aging economies can have similar credit depth and very different credit allocation across firm credit, household credit, real estate and construction credit, public safe assets, and foreign safe asset access. A natural next step is a bank or firm level design that observes loan

purpose, collateral, borrower technology investment, and intermediary balance sheet constraints directly.

7 Data availability

The replication package contains the transformed panel used in the paper, the core sectoral credit file used to construct the dynamic shift share instrument, selected channel variables from the institutional files, the Python code that rebuilds the reported tables, and a Jupyter notebook that runs the sequence. The code also rebuilds the exact sample coefficient first stages, the overlap adjusted IV inference, the diagnostic overidentified cohort specification, the initial sectoral structure controls, and the past growth control diagnostics. The sectoral credit, population, productivity, diffusion, macro, institutional, openness, and KOF globalisation sources are cited in the text and in the bibliography. Some raw provider files are too large to redistribute in the manuscript package, so the package records the data source inventory and stores the transformed variables used by the analysis.

Funding

This work was supported by ANID Chile under Fondecyt grant number 11251916, awarded to María Haydée Fonseca-Mairena.

CRediT author statement

Both authors contributed equally to all aspects of the manuscript. María Haydée Fonseca-Mairena and Octavio Martínez-Baltodano: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review and editing. María Haydée Fonseca-Mairena: Funding acquisition.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the authors used ChatGPT in order to improve wording in selected parts of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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A Appendix

Proofs

Proof of Proposition 3.2. Differentiate Equation (3.5) with respect to A, holding S^G, S^*, $\bar{B}$, and Ω fixed. Since Equation (3.4) gives $dP/dA = -dC^H/dA$,

$$R_A^P(A,P,\Omega) - R_P^P(A,P,\Omega)\frac{\partial C^H}{\partial A} = \phi - \left(\chi_H + m_C(C^H)\right)\frac{\partial C^H}{\partial A}.$$

Collecting the terms that multiply $\partial C^H/\partial A$ gives the first expression in Equation (3.7). The second expression follows from Equation (3.4). □

Proof of Corollary 3.3. Differentiate Equation (3.5) with respect to S^G, holding A, S^*, $\bar{B}$, and Ω fixed. Since $\partial P/\partial S^G = -\partial C^H/\partial S^G$,

$$-R_P^P(A,P,\Omega)\frac{\partial C^H}{\partial S^G} = -\chi_G - \left(\chi_H + m_C(C^H)\right)\frac{\partial C^H}{\partial S^G}.$$

Solving gives the first expression in Equation (3.8). The derivative with respect to S^* is identical after replacing χ_G with χ_*. The response of P follows from Equation (3.4). □

Proof of Proposition 3.1. Using Equation (3.1) and Equation (3.2), write the private safe credit fixed point as

$$C^H = \Psi(\bar{q} + \phi A - \chi_G S^G - \chi_* S^* - \chi_H C^H, \mathcal{B}).$$

Differentiate both sides with respect to A, holding S^G, S^*, and $\mathcal{B}$ fixed:

$$\frac{\partial C^H}{\partial A} = \Psi_q\left(\phi - \chi_H\frac{\partial C^H}{\partial A}\right).$$

Rearranging gives

$$\left(1 + \Psi_q\chi_H\right)\frac{\partial C^H}{\partial A} = \Psi_q\phi.$$

Since $\Psi_q > 0$, $\phi > 0$, and $\chi_H > 0$, Equation (3.3) follows. □

Proof of Proposition 3.4. For an interior choice, the first order condition from Equation (3.9) is

$$\lambda(A)\Gamma(P + \theta C^F, \Omega) + \zeta(A)J(C^H, \Omega) - \mu(A)H(C^H, \Omega) - q^I - \kappa u = 0.$$

Solving gives Equation (3.10). Differentiating with respect to P, C^F, and C^H, and then with respect to A, gives Equation (3.11) and Equation (3.12). The firm collateral cross partial is $\lambda'(A)\theta\Gamma_1(P + \theta C^F, \Omega)/\kappa$, which is nonnegative when $\theta \geq 0$. The signs follow from the maintained assumptions. □

Proof of Proposition 3.5. Using Equation (3.13), the residualized population projection coefficient on the aging by firm sector credit interaction is proportional to

$$\rho_h \frac{\partial^2 u^*}{\partial A \, \partial P}$$

when the residual component is mean independent of the residualized interaction after controls and fixed effects. Since $\rho_h > 0$ and Proposition 3.4 gives a positive cross partial, the income sign is positive. For TFP, the analogous term is $\tau_h \partial^2 u^* / \partial A \partial P$. The sign is informative only when the measured TFP component loads on firm upgrading and the measurement residual is not dominant. □

Proof of Proposition 3.6. Project the outcome on $Z_M = \pi(\Omega) Z_T + [1 - \pi(\Omega)] Z_N$. Under orthogonality of Z_T and Z_N, the numerator of the projection coefficient is proportional to

$$\pi(\Omega) b_T \operatorname{Var}(Z_T) + [1 - \pi(\Omega)] b_N(\Omega) \operatorname{Var}(Z_N).$$

The denominator is positive. The coefficient is positive exactly when this numerator is positive. Rearranging yields Equation (3.16). Because $\pi'(\Omega) > 0$, weaker absorptive capacity lowers the weight on true technology finance and can reverse the measured sign. □

Proof of Proposition 4.1. Write $N_{it} = \sum_{j \in \mathcal{P}} s_{ij,t-L\mathcal{G}-i,j,t}$ and $D_{it} = \sum_j s_{ij,t-L\mathcal{G}-i,j,t}$. Then $Z_{it}^P = N_{it} / D_{it}$. For sector k,

$$\frac{\partial N_{it}}{\partial \ell_{-i,k,t}} = \mathbb{1}\{k \in \mathcal{P}\} s_{ik,t-L\mathcal{G}-i,k,t}, \qquad \frac{\partial D_{it}}{\partial \ell_{-i,k,t}} = s_{ik,t-L\mathcal{G}-i,k,t}.$$

The quotient rule gives

$$\frac{\partial Z_{it}^P}{\partial \ell_{-i,k,t}} = \frac{\mathbb{1}\{k \in \mathcal{P}\} s_{ik,t-L\mathcal{G}-i,k,t} D_{it} - N_{it} s_{ik,t-L\mathcal{G}-i,k,t}}{D_{it}^2}.$$

Using $Z_{it}^P = N_{it} / D_{it}$ and $\omega_{ik,t} = s_{ik,t-L\mathcal{G}-i,k,t} / D_{it}$ yields Equation (4.7). □

Additional tables and diagnostics

The appendix tables are cited here for completeness. Credit reallocation, first-stage, and instrument diagnostics are reported in Tables A.1 to A.7, A.26 and A.27. Mechanism, scale, horizon, and alternative-aging checks are reported in Tables A.8 to A.17. Robustness, exclusion, crisis, and country-trend checks are reported in Tables A.19 to A.25, A.29, A.30 and A.33 to A.35. Common-sample, initial-control, additional inference, open-economy, and support diagnostics are reported in Tables A.18, A.28, A.31, A.32 and A.36 to A.50.

Table A.1: Cohort instrument diagnostic for aging and credit direction

Outcome	Coefficient	Standard error	p value	Countries	First stage F
Firm credit share	-8.583**	(3.377)	0.012	108	6132.6
Household credit share	8.583**	(3.377)	0.012	108	6132.6
Private safe credit share	5.207*	(2.827)	0.069	89	5174.3
Firm sector credit share	-2.013	(2.749)	0.466	87	6634.3
Real estate and construction share	-1.637	(1.350)	0.228	91	5366.5

Notes: The dependent variables are shares of total private credit. Coefficients are reported in percentage points for a one standard deviation increase in the old population share. Aging is instrumented with the share of the population aged 50 and over fifteen years earlier. Each column includes country effects, year effects, lagged income per person, trade openness, investment over GDP, and public debt over GDP. Standard errors are clustered by country. This table is a diagnostic for the reallocation fact, not the main causal design.

Table A.2: Exact sample coefficient first stages for the interaction terms

Outcome sample	Endogenous variable	Excluded instrument	Coefficient	Standard error	p value	Observations	Countries
GDP per person, five year	Aging times firm	Cohort predictor	-0.255	(0.280)	0.365	1369	83
GDP per person, five year	Aging times firm	Firm shift share	0.159**	(0.071)	0.028	1369	83
GDP per person, five year	Aging times firm	Private safe shift share	0.072	(0.063)	0.254	1369	83
GDP per person, five year	Aging times firm	Cohort times firm shift share	0.746***	(0.099)	0.000	1369	83
GDP per person, five year	Aging times firm	Cohort times private safe shift share	-0.058	(0.074)	0.434	1369	83
GDP per person, five year	Aging times safe	Cohort predictor	0.665*	(0.347)	0.058	1369	83
GDP per person, five year	Aging times safe	Firm shift share	-0.105*	(0.061)	0.086	1369	83
GDP per person, five year	Aging times safe	Private safe shift share	0.018	(0.087)	0.838	1369	83
GDP per person, five year	Aging times safe	Cohort times firm shift share	-0.209***	(0.069)	0.003	1369	83
GDP per person, five year	Aging times safe	Cohort times private safe shift share	0.540***	(0.096)	0.000	1369	83
TFP, five year	Aging times firm	Cohort predictor	-0.286	(0.287)	0.322	1210	67
TFP, five year	Aging times firm	Firm shift share	0.093	(0.074)	0.215	1210	67
TFP, five year	Aging times firm	Private safe shift share	0.081	(0.070)	0.255	1210	67
TFP, five year	Aging times firm	Cohort times firm shift share	0.779***	(0.096)	0.000	1210	67
TFP, five year	Aging times firm	Cohort times private safe shift share	-0.052	(0.074)	0.483	1210	67
TFP, five year	Aging times safe	Cohort predictor	0.685*	(0.368)	0.067	1210	67
TFP, five year	Aging times safe	Firm shift share	-0.047	(0.066)	0.481	1210	67
TFP, five year	Aging times safe	Private safe shift share	0.032	(0.099)	0.750	1210	67
TFP, five year	Aging times safe	Cohort times firm shift share	-0.232***	(0.074)	0.003	1210	67
TFP, five year	Aging times safe	Cohort times private safe shift share	0.537***	(0.101)	0.000	1210	67

Notes: The table reports coefficient first stages on the exact second stage samples. The dependent variables are the endogenous interactions between standardized aging and standardized credit shares. Regressions residualize country effects, year effects, lagged income per person, trade openness, investment over GDP, and public debt over GDP. Standard errors are clustered by country.

Table A.3: IV inference with overlapping forward windows

Outcome	Coefficient	Clustered se	Clustered p	HAC lags	HAC se	HAC p
GDP per person, five year	1.957**	(0.876)	0.028	4	(0.681)	0.005
TFP, five year	0.506	(0.476)	0.292	4	(0.367)	0.173
GDP per person, ten year	-0.725	(4.291)	0.866	9	(3.542)	0.839
TFP, ten year	-8.489	(44.831)	0.851	9	(37.819)	0.823

Notes: The coefficient is the IV coefficient on the aging by firm sector credit interaction. HAC standard errors are computed within country on the IV score with Bartlett weights. Four lags are used for five year forward growth windows and nine lags for ten year windows. This correction addresses overlap in the dependent variable but not the exclusion restriction.

Table A.4: Overidentified cohort diagnostic

Outcome	Coefficient	Standard error	p value	Minimum first stage F	Hansen J	df	J p value
GDP per person, five year	1.163*	(0.655)	0.080	38.4	6.003	3	0.111
TFP, five year	0.482	(0.479)	0.319	45.7	2.573	3	0.462

Notes: The baseline excluded instruments are augmented with the lagged share aged 50 to 64, interacted with the same firm sector and private safe shift shares. The Hansen statistic is reported only as a diagnostic because the additional cohort predictor can violate exclusion through channels other than current aging.

Table A.5: Anatomy of the dynamic credit shift shares

Sector	Lagged exposure	External shift	Predicted total share	Firm sector numerator	Private safe numerator
Household	0.340	1.053	0.360		0.754
Agriculture	0.055	0.855	0.048		
Manufacturing and mining	0.167	0.870	0.151	0.786	
Real estate and construction	0.097	1.045	0.103		0.270
Trade and accommodation	0.157	0.938	0.152		
Transport and communication	0.035	0.996	0.035	0.222	
Other	0.171	1.003	0.173		

Notes: The table reports the five year GDP per person IV sample. Lagged exposure is the country sector share of known private credit categories five years earlier. External shift is the leave one out change in the global sector share from the lag year to the base year. Predicted total share is the sector contribution to the denominator of the dynamic shift share. The last two columns decompose the numerator of the firm sector and private safe predicted shares. The diagnostic makes the identifying variation behind the ratio instrument transparent.

Table A.6: First order anatomy of the firm sector credit shift share instrument

Sector	Role	Influence share	Mean influence	Mean weight	Correlation with instrument
Manufacturing, mining, and quarrying	firm sector numerator	39.7	0.111	0.151	0.972
Household credit	private safe numerator	18.5	-0.052	0.360	-0.678
Trade and accommodation	denominator only	11.0	-0.031	0.152	0.215
Other sectors	denominator only	10.7	-0.029	0.173	-0.176
Transport and communication	firm sector numerator	9.8	0.027	0.035	0.420
Real estate and construction	private safe numerator	6.6	-0.019	0.103	-0.075
Agriculture	denominator only	3.7	-0.010	0.048	0.212

Notes: The table reports the first order influence of each sector on the ratio shift share instrument for firm sector credit in the five year GDP per person IV sample. The influence of sector k is $\omega_{ik,t}(\mathbb{1}\{k \in \mathcal{P}\} - Z_{it}^{P})$, where $\omega_{ik,t}$ is the sector contribution to the predicted denominator. Influence shares use mean absolute influence. Correlations are computed between each sector contribution and the firm sector credit shift share.

Table A.7: Reduced form relation for the interaction instrument.

Outcome	Reduced form coefficient	Standard error	p value	Observations	Countries
TFP, 5 year	0.619***	(0.215)	0.005	1482	74
TFP, 10 year	0.638***	(0.220)	0.005	792	54
GDP per person, 5 year	0.814***	(0.244)	0.001	1678	92
GDP per person, 10 year	0.529**	(0.221)	0.020	853	64
Internet, 5 year	1.771	(2.078)	0.396	1424	92
Mobile, 5 year	-0.648	(1.893)	0.733	1667	92
Technology payments in, 5 year	-0.482	(2.467)	0.846	1504	89

Notes: The reported regressor is the interaction between the lagged cohort predictor and the dynamic sectoral firm sector credit shift share. The reduced form includes the cohort predictor, the firm sector and private safe shift shares, and the private safe interaction instrument. The controls and fixed effects match the IV specification. Standard errors are clustered by country.

Table A.8: Mechanism decomposition for the IV interaction

Outcome	Coef.	SE	p value	N	Countries
GDP per person growth	1.957**	(0.876)	0.028	1369	83
TFP growth	0.506	(0.476)	0.292	1210	67
Investment share change	0.182	(0.777)	0.815	981	80
Working age share change	0.081	(0.219)	0.714	981	80
Current account change	1.679	(2.406)	0.487	981	80

Notes: The reported coefficient is the instrumented aging by firm sector credit interaction. The endogenous variables and excluded instruments are the same as in Table 2. Investment, working age share, and current account outcomes are five year forward changes divided by five. Standard errors are clustered by country.

Table A.9: Interquartile scale of the interaction moments

	TFP growth	GDP per capita growth	Broadband diffusion
Firm sector credit, p75 minus p25	0.432***	0.640***	0.225
	(0.153)	(0.235)	(0.138)
Private safe credit, p75 minus p25	-0.367	-0.511*	-0.311**
	(0.271)	(0.292)	(0.130)

Notes: Each entry is the change in the marginal relation between a one standard deviation increase in aging and the outcome when the credit share moves from the twenty fifth to the seventy fifth percentile of the estimation sample. The numbers use the standardized baseline specification. Standard errors are clustered by country.

Table A.10: Natural unit scale check

	TFP growth	GDP per capita growth	Broadband diffusion
Aging times firm sector credit	0.067***	0.098***	0.043
	(0.024)	(0.036)	(0.026)
Aging times private safe credit	-0.032	-0.044*	-0.033**
	(0.024)	(0.025)	(0.014)

Notes: Old population and credit shares are measured in percentage points before multiplication. Coefficients and standard errors are scaled by ten, so each cell corresponds to the interaction of a one percentage point increase in the old share with a ten percentage point increase in the credit share. Standard errors are clustered by country.

Table A.11: Horizon sensitivity

	TFP growth		GDP per capita growth		Broadband diffusion	
	Firm sector	Private safe	Firm sector	Private safe	Firm sector	Private safe
3 year horizon	0.319*	-0.486**	0.613**	-0.443	0.187*	-0.135*
	(0.188)	(0.210)	(0.261)	(0.270)	(0.100)	(0.069)
5 year horizon	0.381***	-0.257	0.560***	-0.355*	0.244	-0.262**
	(0.135)	(0.190)	(0.205)	(0.203)	(0.150)	(0.110)
7 year horizon	0.402***	-0.173	0.463**	-0.294	0.288	-0.330**
	(0.126)	(0.180)	(0.181)	(0.179)	(0.187)	(0.132)
10 year horizon	0.319**	-0.273	0.326**	-0.191	0.123	-0.119
	(0.139)	(0.180)	(0.146)	(0.176)	(0.382)	(0.275)

Notes: Log outcomes are annualized for TFP and GDP per person. Diffusion outcomes are changes in transformed penetration measures. The ten year horizon is included to check whether the baseline five year window is dominated by shorter macro cycles.

Table A.12: Alternative aging measure

	TFP growth	GDP per capita growth	Broadband diffusion
Old dependency times firm sector credit	0.345**	0.548***	0.228
	(0.140)	(0.200)	(0.152)
Old dependency times private safe credit	-0.252	-0.292	-0.247**
	(0.184)	(0.195)	(0.111)

Notes: The aging variable is the ratio of the population aged 65 and over to the working age population aged 15 to 64. The table repeats the baseline interaction design with country and year effects and the baseline controls.

Table A.13: Aging, credit direction, and future technology

	TFP growth	GDP per capita growth	Internet diffusion	Broadband diffusion	Mobile diffusion
Aging times firm sector credit	0.381***	0.560***	-0.004	0.244	0.055
	(0.135)	(0.205)	(0.105)	(0.150)	(0.139)
Aging times private safe credit	-0.257	-0.355*	0.024	-0.262**	-0.139*
	(0.190)	(0.203)	(0.098)	(0.110)	(0.081)
Observations	1067	1193	1015	603	1182
Countries	67	81	80	78	81

Notes: The interacting variables are standardized before multiplication. The baseline private safe credit measure is household credit plus real estate and construction credit as a share of total private credit. All columns include country and year effects and the baseline macro controls. Standard errors clustered by country are in parentheses.

Table A.14: Measurement checks for credit categories

Pair	Correlation	Observations	Median of first variable
Firm sector credit and tradable credit	0.893	3101	0.181
Firm sector credit and nontradable credit	-0.022	3022	0.176
Private safe credit and household credit	0.939	3316	0.420
Private safe credit and real estate credit	0.229	3316	0.420

Notes: The table reports raw correlations in the transformed sectoral credit panel. It is not a validation with firm level technology data. It documents that the baseline firm sector measure is closely related to the tradable sectoral share, while the private safe measure is closely related to household credit.

Table A.15: Heterogeneity by income group

	TFP growth	GDP per capita growth	Broadband diffusion
High income: Aging times firm sector credit	0.365	0.874***	0.121
	(0.322)	(0.252)	(0.233)
High income: Aging times private safe credit	-0.077	0.175	-0.089
	(0.242)	(0.251)	(0.196)
Middle and low income: Aging times firm sector credit	-0.649*	0.722	-0.289**
	(0.353)	(0.527)	(0.132)
Middle and low income: Aging times private safe credit	-1.870***	-0.670	-0.324
	(0.536)	(0.443)	(0.199)

Notes: The split is based on the income group indicator included in the transformed panel. The middle and low income group pools all non high income observations to retain precision.

Table A.16: Countries in the baseline TFP sample

Income group	Count	Countries
High income	37	Austria; Bahrain; Belgium; Bulgaria; Chile; Costa Rica; Cyprus; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; Iceland; Ireland; Israel; Italy; Japan; Latvia; Lithuania; Malta; New Zealand; Norway; Panama; Poland; Portugal; Russia; Saudi Arabia; Singapore; Slovak Republic; Slovenia; South Korea; Spain; Switzerland; United Kingdom
Low income	1	Sierra Leone
Lower middle income	11	Honduras; India; Jordan; Kenya; Kyrgyz Republic; Lesotho; Morocco; Philippines; Sri Lanka; Tanzania; Tunisia
Upper middle income	17	Albania; Argentina; Armenia; Botswana; Colombia; Dominican Republic; Guatemala; Kazakhstan; Malaysia; Mauritius; Mexico; Mongolia; Peru; South Africa; Thailand; Turkey; Ukraine

Notes: Countries are those with nonmissing observations in the baseline TFP regression after applying the country year window, controls, and credit variables. The list is included to make the income heterogeneity transparent.

Table A.17: Institutional capacity and the interaction moments

	TFP growth	GDP per capita growth	Broadband diffusion
Aging times firm sector credit	-0.130	0.988*	0.086
	(0.308)	(0.512)	(0.184)
Aging times firm sector credit times institutional capacity	0.844**	0.959**	-0.123
	(0.376)	(0.424)	(0.191)
Aging times private safe credit	-0.409	-0.255	-0.268*
	(0.440)	(0.383)	(0.148)
Aging times private safe credit times institutional capacity	0.520	0.432	0.048
	(0.368)	(0.362)	(0.168)
Observations	545	630	468
Countries	57	68	65

Notes: The table adds institutional capacity, its lower order interactions, and the triple interactions with aging and credit shares. Institutional capacity is the average of the World Governance Indicator measures for rule of law, regulatory quality, government effectiveness, and control of corruption in the QoG data, standardized in the analysis panel. All specifications include country and year effects and the baseline controls. Standard errors are clustered by country.

Table A.18: IV robustness to commodity and transition exposure

Sample	Outcome	Coefficient	Standard error	p value	Countries	Minimum first stage F
Baseline	GDP per person	1.957**	(0.876)	0.028	83	49.0
Baseline	TFP	0.506	(0.476)	0.292	67	62.5
Excluding high oil rent countries	GDP per person	1.563**	(0.716)	0.033	67	55.5
Excluding high oil rent countries	TFP	0.552	(0.412)	0.186	55	71.0
Excluding transition economies	GDP per person	1.885**	(0.874)	0.035	66	60.4
Excluding transition economies	TFP	0.350	(0.461)	0.452	52	76.1

Notes: The table repeats the IV specification in Table 2. High oil rent countries are countries above the sample seventy fifth percentile of average oil rents in the Quality of Government file. Transition economies are former socialist and post Soviet economies listed in the replication code. Standard errors are clustered by country.

Table A.19: IV sensitivity to financial crisis windows

Sample	Coefficient	Standard error	p value	Countries	Minimum first stage F
Baseline	1.957**	(0.876)	0.028	83	49.0
Exclude base years 1997 to 1999 and 2007 to 2010	1.755**	(0.668)	0.010	82	46.5
Exclude base years 2007 to 2010	1.727**	(0.687)	0.014	82	51.4
Exclude windows crossing 2008 to 2009	1.613***	(0.525)	0.003	82	65.0
Exclude banking crisis years	1.972**	(0.917)	0.035	83	44.7
Exclude all crisis indicators	1.965**	(0.860)	0.025	83	41.4

Notes: The dependent variable is five year annualized GDP per person growth. Each row reports the IV coefficient on the aging by firm sector credit interaction. All specifications instrument aging, firm sector credit, private safe credit, and both interactions using the same excluded instruments as the main IV. Standard errors are clustered by country.

Table A.20: Leave one sector out IV diagnostics

Excluded sector	Coefficient	Standard error	p value	Countries	Minimum first stage F
Household credit	9.438	(49.281)	0.849	83	18.0
Agriculture	1.795	(1.578)	0.259	83	47.1
Manufacturing, mining, and quarrying	1.699	(1.405)	0.230	83	22.6
Real estate and construction	2.467**	(1.053)	0.022	83	50.9
Trade and accommodation	1.091	(0.802)	0.178	83	46.7
Transport and communication	2.157**	(0.997)	0.033	83	51.5
Other sectors	3.674**	(1.401)	0.010	83	42.0

Notes: Each row rebuilds the dynamic shift share instruments after removing one sector from the predicted numerator and denominator system. The dependent variable is five year annualized GDP per person growth. The reported coefficient is the aging by firm sector credit interaction. Standard errors are clustered by country.

Table A.21: IV controls for alternative exclusion channels

Additional controls	Coefficient	Standard error	p value	Countries	Minimum first stage F
Baseline controls	1.957**	(0.876)	0.028	83	49.0
Export share control	2.002**	(0.876)	0.025	83	49.0
Oil rent control	1.978**	(0.872)	0.026	83	44.6
Export and oil rent controls	2.050**	(0.873)	0.021	83	44.5
Human capital control	1.516**	(0.654)	0.024	69	43.5
Institutional capacity control	2.291	(4.095)	0.578	70	3.0
Absorptive capacity control	2.031**	(0.801)	0.014	70	32.7

Notes: The dependent variable is five year annualized GDP per person growth. Each row adds the listed channel controls to the baseline IV controls. Export and oil rent controls use World Development Indicators variables in the Quality of Government channel file. Human capital and institutional capacity come from the absorptive capacity file. The row with institutional capacity is reported only as a diagnostic because the first stages are weaker in that smaller sample.

Table A.22: IV diagnostic controlling for initial sectoral credit structure

Outcome	Coefficient	Standard error	p value	Observations	Minimum first stage F
GDP per person, five year	1.664**	(0.619)	0.010	942	48.9
TFP, five year	0.025	(0.505)	0.961	880	42.9

Notes: The specification adds interactions between the cohort predictor and each country initial sectoral credit shares, measured as country means over 1980 to 1994 when available. The goal is to separate the credit allocation instrument from predetermined industrial and credit structure. Standard errors are clustered by country.

Table A.23: Aging and sectoral credit components in TFP growth

Sample	Manufacturing, mining, and quarrying	Transport and communication	Agriculture	Trade and accommodation	Real estate and construction
Full sample	0.426***	0.065	1.043***	0.029	0.230
	(0.147)	(0.133)	(0.347)	(0.379)	(0.144)
Middle and low income	-0.660*	-0.683	0.299	-2.000***	0.876
	(0.394)	(0.557)	(1.024)	(0.508)	(0.650)

Notes: Each cell is the coefficient on the interaction between the old population share and the listed sectoral credit share in a TFP growth regression. Each specification includes the old population share, the listed sectoral share, the private safe credit share, the aging and private safe credit interaction, country and year effects, and the baseline controls. Standard errors are clustered by country.

Table A.24: Development sign frontier

Outcome	High income coefficient	Middle and low income coefficient	Technology finance weight threshold
TFP growth	0.365	-0.649	0.640
GDP per capita growth	0.874	0.722	
Broadband diffusion	0.121	-0.289	0.705

Notes: The last column is reported only when the high income coefficient is positive and the middle and low income coefficient is negative. It is the technology finance weight that would make the normalized mixture in Proposition 3.6 change sign when the two sample coefficients are used as diagnostic slopes.

Table A.25: Decomposing private safe credit

	TFP growth	GDP per capita growth	Broadband diffusion
Private safe credit: aging times firm sector credit	0.381***	0.560***	0.244
	(0.135)	(0.205)	(0.150)
Private safe credit: aging times safe credit	-0.257	-0.355*	-0.262**
	(0.190)	(0.203)	(0.110)
Real estate credit: aging times firm sector credit	0.592***	0.789***	0.487***
	(0.133)	(0.165)	(0.103)
Real estate credit: aging times safe credit	0.097	-0.400***	-0.069
	(0.141)	(0.149)	(0.047)
Household credit: aging times firm sector credit	0.418***	0.834***	0.310**
	(0.127)	(0.187)	(0.150)
Household credit: aging times safe credit	-0.327*	-0.086	-0.256**
	(0.198)	(0.249)	(0.108)

Notes: Each pair of rows reestimates the same specification after replacing the private safe credit measure. The baseline measure is household credit plus real estate and construction credit.

Table A.26: Reduced form pretrend diagnostic for the interaction instrument

Outcome	Coef.	SE	p value	N	Countries
Past TFP growth	0.447	(0.284)	0.121	1362	72
Past GDP per person growth	0.814**	(0.310)	0.010	1524	88
Future TFP growth	0.183	(0.185)	0.326	1362	72
Future GDP per person growth	0.629***	(0.211)	0.004	1524	88

Notes: The regressor is the excluded interaction instrument, defined as the cohort exposure instrument times the dynamic sectoral credit shift share. Past outcomes are five year annualized changes ending at the base year. The diagnostic reports how past outcomes relate to the excluded interaction instrument and helps define the scope of the identifying variation.

Table A.27: Reduced form windows for the excluded interaction instrument

Outcome window	Coefficient	Standard error	p value	Observations	Countries
Past 3 year TFP growth	0.528**	(0.239)	0.030	1482	74
Past 3 year GDP per person growth	0.515*	(0.280)	0.069	1678	92
Future 3 year TFP growth	0.531**	(0.223)	0.020	1267	74
Future 3 year GDP per person growth	0.683***	(0.245)	0.007	1419	90
Past 5 year TFP growth	0.545**	(0.267)	0.045	1482	74
Past 5 year GDP per person growth	0.461*	(0.268)	0.089	1678	92
Future 5 year TFP growth	0.629**	(0.245)	0.012	1122	73
Future 5 year GDP per person growth	0.583**	(0.225)	0.011	1246	88
Past 10 year TFP growth	0.157	(0.170)	0.360	1482	74
Past 10 year GDP per person growth	0.144	(0.190)	0.452	1673	92
Future 10 year TFP growth	0.638***	(0.220)	0.005	792	54
Future 10 year GDP per person growth	0.529**	(0.221)	0.020	853	64

Notes: The table reports reduced form regressions of past and future annualized outcome growth on the excluded firm sector interaction instrument. Each regression controls for country effects, year effects, the other excluded instruments, lagged income per person, trade openness, investment over GDP, and public debt over GDP. Standard errors are clustered by country.

Table A.28: Past growth controls in the symmetric IV design

Outcome and specification	Past window	Coefficient	Standard error	p value	Observations	Minimum first stage F
GDP per person growth, Baseline	None	1.957**	(0.876)	0.028	1369	49.0
GDP per person growth, Past three year outcome	3 years	1.736*	(0.927)	0.065	1369	48.0
GDP per person growth, Past five year outcome	5 years	1.688*	(1.008)	0.098	1369	46.8
GDP per person growth, Past ten year outcome	10 years	2.058*	(1.117)	0.069	1364	49.0
TFP growth, Baseline	None	0.506	(0.476)	0.292	1210	62.5
TFP growth, Past three year outcome	3 years	0.521	(0.461)	0.262	1210	63.5
TFP growth, Past five year outcome	5 years	0.554	(0.450)	0.223	1210	65.3
TFP growth, Past ten year outcome	10 years	0.448	(0.496)	0.370	1210	66.9

Notes: The table reports the coefficient on the instrumented aging by firm sector credit interaction. Past growth controls are annualized changes ending at the base year. The endogenous variables and excluded instruments are the same as in Table 2. The diagnostic asks whether realized preperiod growth absorbs the five year interaction estimate and reports how the coefficient changes after conditioning on that history.

Table A.29: Country trend IV diagnostic.

Outcome	Coefficient	Standard error	p value	Minimum first stage F	Countries
TFP, 5 year	5.805	(13.845)	0.676	5.95	67
GDP per person, 5 year	-5.660	(16.396)	0.731	6.63	83

Notes: The same excluded instruments are used after adding country specific linear trends. The first stages collapse, so these estimates are not interpreted as substantive causal estimates.

Table A.30: Full coefficients for selected technology regressions

	TFP growth	GDP per capita growth	Broadband diffusion
Aging	0.018	-0.271	0.291
	(0.496)	(0.671)	(0.300)
Firm sector credit	-0.146	-0.968***	-0.534***
	(0.278)	(0.315)	(0.200)
Private safe credit	0.414	0.034	-0.036
	(0.272)	(0.311)	(0.146)
Aging times firm sector credit	0.381***	0.560***	0.244
	(0.135)	(0.205)	(0.150)
Aging times private safe credit	-0.257	-0.355*	-0.262**
	(0.190)	(0.203)	(0.110)
Observations	1067	1193	603
Countries	67	81	78

Notes: This table reports the main effects that are suppressed in the compact baseline table. The diagnostics are computed after absorbing country and year effects and controls.

Table A.31: Outcome sample and common sample comparison

	TFP growth		GDP per capita growth		Broadband diffusion	
	Outcome	Common	Outcome	Common	Outcome	Common
Aging times firm sector credit	0.381***	0.432*	0.560***	1.152***	0.244	0.325**
	(0.135)	(0.251)	(0.205)	(0.299)	(0.150)	(0.157)
Aging times private safe credit	-0.257	0.119	-0.355*	-0.323	-0.262**	-0.181*
	(0.190)	(0.178)	(0.203)	(0.255)	(0.110)	(0.110)
Observations	1067	533	1193	533	603	533

Notes: Outcome columns use the maximum available sample for each dependent variable. Common columns restrict the sample to observations with nonmissing TFP growth, GDP per capita growth, broadband diffusion, baseline regressors, and baseline controls. Standard errors are clustered by country.

Table A.32: Initial outcome controls

	TFP growth	GDP per capita growth	Internet diffusion	Broadband diffusion	Mobile diffusion
Aging times firm sector credit	0.269*	0.560***	-0.055	-0.006	0.012
	(0.148)	(0.205)	(0.073)	(0.085)	(0.096)
Aging times private safe credit	-0.168	-0.355*	-0.211***	-0.044	-0.254***
	(0.172)	(0.203)	(0.074)	(0.053)	(0.066)
Observations	1067	1193	1015	603	1182
Countries	67	81	80	78	81

Notes: Each column adds the level of the corresponding outcome at the base year to the baseline controls.

Table A.33: Robustness of the firm sector credit interaction

	TFP growth	GDP per capita growth	Broadband diffusion
Baseline	0.381***	0.560***	0.244
	(0.135)	(0.205)	(0.150)
Median age	0.466***	0.583**	0.317**
	(0.145)	(0.258)	(0.149)
Nonoverlapping cells	0.322	0.526	1.235
	(0.461)	(0.494)	(1.508)
GMD controls	0.380***	0.757***	0.256*
	(0.134)	(0.239)	(0.149)
Current account and inflation	0.469***	0.528**	0.163
	(0.144)	(0.206)	(0.146)
Crisis controls	0.424***	0.421**	0.184
	(0.120)	(0.202)	(0.166)
GMD open economy controls	0.446***	0.696***	0.173
	(0.146)	(0.230)	(0.148)

Notes: Each row reports the coefficient on aging times firm sector credit. GMD refers to the Global Macro Database controls. The open economy row adds the current account and inflation when available.

Table A.34: Pretrend placebo regressions

	TFP growth	GDP per capita growth	Broadband diffusion
Aging times firm sector credit	-0.019	0.231	0.379*
	(0.298)	(0.382)	(0.213)
Aging times private safe credit	-0.592**	0.053	0.002
	(0.238)	(0.366)	(0.134)

Notes: The dependent variables are five year changes that end at the base year. A precise coefficient in this table is evidence against a strong causal interpretation of the corresponding future window estimate.

Table A.35: Pretrend adjusted future outcome regressions

	TFP growth	GDP per capita growth	Broadband diffusion
Aging times firm sector credit	0.404**	0.688***	0.021
	(0.166)	(0.203)	(0.116)
Aging times private safe credit	-0.293	-0.308*	-0.108
	(0.206)	(0.181)	(0.104)

Notes: Each future outcome regression adds the corresponding five year pretrend ending at the base year as an additional control. The exercise addresses the placebo patterns in the pretrend placebo table. Standard errors are clustered by country.

Table A.36: Country specific linear trend diagnostic

	TFP growth	GDP per capita growth	Broadband diffusion
Aging times firm sector credit	0.514**	0.025	-0.228
	(0.219)	(0.302)	(0.300)
Aging times private safe credit	0.347	-0.436*	-0.245
	(0.247)	(0.227)	(0.166)

Notes: The specification adds a separate linear trend for each country to the baseline controls. This diagnostic is demanding because demographics and credit shares are persistent. It is not used as the main design. Standard errors are clustered by country.

Table A.37: Internal lagged credit instrument diagnostics.

Lag	Outcome	Coefficient	Standard error	p value	Minimum first stage F	Countries
5	TFP, 5 year	0.356	(0.309)	0.254	139.0	66
5	GDP per person, 5 year	1.463***	(0.391)	0.000	149.6	82
10	TFP, 5 year	0.718	(0.681)	0.296	7.8	64
10	GDP per person, 5 year	2.775	(1.684)	0.103	4.1	79
15	TFP, 5 year	95.010	(23435.809)	0.997	3.1	51
15	GDP per person, 5 year	6.888	(107.030)	0.949	3.1	63

Notes: The table instruments firm sector credit and its aging interaction with lagged firm sector credit and its interaction with the lagged cohort predictor. This is not the preferred design because lagged domestic credit can remain endogenous. The longer lag estimates are reported to show why the dynamic external shift share is preferred.

Table A.38: Real interest rate channel diagnostic

	TFP growth	GDP per capita growth	Broadband diffusion
Aging times firm sector credit	0.995***	0.789**	0.137
	(0.261)	(0.380)	(0.199)
Aging times private safe credit	0.341	-0.033	-0.238*
	(0.207)	(0.251)	(0.135)
Aging times real long rate	-0.268*	0.363*	0.058
	(0.161)	(0.196)	(0.068)
Aging times real short rate	0.783**	0.004	0.048
	(0.339)	(0.343)	(0.145)
Observations	677	717	398
Countries	45	49	49

Notes: Real long and short rates are nominal rates minus inflation, winsorized at the first and ninety ninth percentiles and standardized. The table adds those rates and their interactions with aging to the baseline specification. The smaller sample reflects rate data availability. Standard errors are clustered by country.

Table A.39: Open economy and public debt interactions

	TFP growth	GDP per capita growth	Broadband diffusion
Aging times firm sector credit	0.472***	0.536***	0.146
	(0.149)	(0.207)	(0.149)
Aging times private safe credit	-0.205	-0.351*	-0.267**
	(0.163)	(0.205)	(0.106)
Aging times public debt	0.099	-0.190	0.071
	(0.207)	(0.135)	(0.058)
Aging times current account	-0.069	0.413**	0.050
	(0.202)	(0.162)	(0.065)

Notes: The specification adds interactions of aging with public debt and the current account, together with the current account level. Public debt is already part of the baseline controls. The exercise asks whether the firm sector credit interaction survives when public and external balance sheet margins are allowed to absorb part of safe claim demand.

Table A.40: IV diagnostic with KOF globalisation controls

Outcome	Added control	Coefficient	Standard error	p value	Observations	Minimum first stage F
GDP per person, five year	Financial globalisation	1.935**	(0.844)	0.025	1369	42.2
GDP per person, five year	Economic globalisation	1.941**	(0.835)	0.023	1369	42.6
GDP per person, five year	Trade globalisation	1.971**	(0.846)	0.022	1369	50.1
GDP per person, five year	Overall globalisation	1.963**	(0.897)	0.032	1369	41.1
GDP per person, five year	Financial and trade globalisation	1.953**	(0.822)	0.020	1369	43.8
TFP, five year	Financial globalisation	0.504	(0.477)	0.295	1210	55.7
TFP, five year	Economic globalisation	0.465	(0.474)	0.330	1210	53.6
TFP, five year	Trade globalisation	0.413	(0.472)	0.385	1210	61.2
TFP, five year	Overall globalisation	0.457	(0.466)	0.330	1210	47.1
TFP, five year	Financial and trade globalisation	0.413	(0.475)	0.387	1210	56.0

Notes: The table reports the coefficient on the instrumented aging by measured firm sector credit interaction after adding standardized KOF globalisation controls to the symmetric IV specification. The baseline controls are lagged income per person, trade openness, investment over GDP, and public debt over GDP. All specifications include country and year effects. Standard errors are clustered by country.

Table A.41: Capital account openness diagnostic

	TFP growth	GDP per capita growth	Broadband diffusion
Aging times firm sector credit	0.349**	0.546***	0.226
	(0.151)	(0.201)	(0.151)
Aging times private safe credit	-0.239	-0.271	-0.256**
	(0.180)	(0.201)	(0.109)
Aging times capital account openness	-0.167	-0.376***	-0.065
	(0.199)	(0.127)	(0.129)

Notes: The table adds the Chinn and Ito capital account openness index and its interaction with aging to the baseline specification. The exercise addresses the possibility that foreign safe assets and capital account access absorb part of aging induced safe claim demand. Standard errors are clustered by country.

Table A.42: Heterogeneity by financial depth

	TFP growth	GDP per capita growth	Broadband diffusion
Low financial depth: Aging times firm sector credit	1.925**	2.357**	-0.559
	(0.778)	(1.096)	(0.516)
Low financial depth: Aging times private safe credit	0.521	-0.430	-0.481*
	(0.595)	(0.704)	(0.278)
High financial depth: Aging times firm sector credit	0.086	-0.942	-0.065
	(0.414)	(0.869)	(0.210)
High financial depth: Aging times private safe credit	0.147	-0.533	0.436
	(0.417)	(0.754)	(0.303)

Notes: The split uses the median of private credit over GDP in the estimation sample for each outcome. The sample is smaller because private debt data are available for fewer observations.

Table A.43: Coefficient stability diagnostic

	TFP growth		GDP per capita growth		Broadband diffusion	
	No controls	Controls	No controls	Controls	No controls	Controls
Aging times firm sector credit	0.359	0.381	0.637	0.560	0.294	0.244
Aging times private safe credit	-0.125	-0.257	-0.004	-0.355	-0.258	-0.262

Notes: The table follows the coefficient stability logic of Oster by comparing the interaction coefficient before and after adding the baseline macro controls, after absorbing country and year effects. The accompanying CSV file reports residualized R squared values and the implied coefficient under proportional selection with $R_{\max} = 1.3R^2_{\text{controls}}$, capped at 0.99.

Table A.44: Imperfect exclusion sensitivity

Outcome	IV coefficient	Coefficient shift from a unit direct effect	Direct effect that sets coefficient to zero	Observations	Countries
GDP per person, five year	1.957	1.663	1.177	1369	83
GDP per person, ten year	-0.725	5.462	-0.133	635	54
TFP, five year	0.506	1.424	0.355	1210	67

Notes: The table follows the imperfect exclusion logic in Conley et al. (2012). It reports how the IV coefficient on the aging by firm sector credit interaction would move if the excluded interaction instrument had a direct effect on the outcome after the baseline controls. The third column gives the direct effect size that would set the reported interaction coefficient to zero. The exercise is a local sensitivity calculation, not a proof of instrument validity.

Table A.45: Country and two way clustered inference

Outcome	Term	Coefficient	Country SE	Country and year SE
TFP growth	Aging times firm sector credit	0.381***	(0.135)	(0.122)
	Aging times private safe credit	-0.257	(0.190)	(0.179)
GDP per capita growth	Aging times firm sector credit	0.560***	(0.205)	(0.245)
	Aging times private safe credit	-0.355*	(0.203)	(0.227)
Broadband diffusion	Aging times firm sector credit	0.244	(0.150)	(0.157)
	Aging times private safe credit	-0.262**	(0.110)	(0.104)

Notes: The table reports the baseline interaction coefficients with standard errors clustered by country and with two way clustering by country and year. Stars use the country clustered p values so that the coefficient notation matches the baseline tables. All specifications include country and year effects and the baseline controls.

Table A.46: Cluster and wild cluster inference

Outcome	Term	Coefficient	Cluster p	Wild p	Countries
TFP growth	Aging times firm sector credit	0.381	0.005	0.015	67
TFP growth	Aging times private safe credit	-0.257	0.177	0.230	67
GDP per capita growth	Aging times firm sector credit	0.560	0.006	0.010	81
GDP per capita growth	Aging times private safe credit	-0.355	0.080	0.120	81
Broadband diffusion	Aging times firm sector credit	0.244	0.104	0.155	78
Broadband diffusion	Aging times private safe credit	-0.262	0.017	0.045	78

Notes: Cluster p values use the country clustered covariance matrix. Wild p values are Rademacher wild cluster bootstrap p values with 199 replications. The table reports coefficients as well as p values so that the sign and economic magnitude are visible together.

Table A.47: Influential old economies and crisis year exclusions

	TFP growth	GDP per capita growth	Broadband diffusion
Main sample	0.381***	0.560***	0.244
	(0.135)	(0.205)	(0.150)
Exclude five oldest economies	0.396***	0.513**	0.215
	(0.133)	(0.235)	(0.160)
Exclude ten oldest economies	0.409***	0.532**	0.264*
	(0.137)	(0.239)	(0.148)
Exclude crisis years	0.346***	0.492**	0.265*
	(0.133)	(0.206)	(0.146)

Notes: Each entry is the coefficient on aging times firm sector credit. The five oldest economies by maximum old population share in the estimation data are Japan, Italy, Germany, Greece, and Portugal. The ten oldest add Bulgaria, Finland, Latvia, Lithuania, and Estonia. Crisis years exclude observations with a recorded banking, sovereign debt, or currency crisis. Standard errors are clustered by country.

Table A.48: Quadratic interaction check

	TFP growth	GDP per capita growth	Broadband diffusion
Linear firm sector interaction	0.224	0.478**	0.233
	(0.192)	(0.226)	(0.166)
Quadratic firm sector interaction	-0.038	-0.135	-0.046
	(0.129)	(0.134)	(0.117)
Linear private safe interaction	-0.419	-0.468**	-0.232*
	(0.285)	(0.229)	(0.133)
Quadratic private safe interaction	0.162	0.230**	0.034
	(0.165)	(0.091)	(0.063)

Notes: The quadratic check adds squared credit shares and their interactions with aging. It is used to see whether the baseline interaction is a local linear approximation rather than a tail driven relation.

Table A.49: Support of baseline variables

Outcome	Variable	p05	p25	p50	p75	p95
TFP growth	Old population share	0.028	0.054	0.110	0.150	0.173
TFP growth	Firm sector credit share	0.059	0.108	0.171	0.253	0.392
TFP growth	Private safe credit share	0.178	0.318	0.452	0.573	0.711
GDP per capita growth	Old population share	0.025	0.048	0.099	0.149	0.172
GDP per capita growth	Firm sector credit share	0.058	0.105	0.169	0.251	0.403
GDP per capita growth	Private safe credit share	0.173	0.308	0.443	0.566	0.707
Broadband diffusion	Old population share	0.023	0.051	0.099	0.155	0.181
Broadband diffusion	Firm sector credit share	0.047	0.090	0.143	0.208	0.320
Broadband diffusion	Private safe credit share	0.228	0.370	0.488	0.582	0.718

Notes: Entries are raw shares in the estimation samples for the selected outcomes. The table shows where the identifying variation lies and reports the observed support for marginal effects.

Table A.50: Data source inventory used to rebuild the design.

Source group	Decision for the revision
Sectoral credit	Müller and Verner credit data are used to construct firm sector credit, private safe credit, and the dynamic leave one out shift share instrument.
Demography	World Population Prospects variables are used for old population shares, dependency ratios, and predetermined cohort exposure.
Aggregate outcomes	Penn World Table outcomes are used for TFP and GDP per person. WDI diffusion variables are retained only as auxiliary technology diagnostics.
Institutions and absorptive capacity	QoG selected channels enter the mechanism diagnostics. V Dem and DPI were reviewed but not used in the main IV because their variation is institutional and can affect technology directly.
Macro, debt, and openness	WEO, GDD, historical public debt, Chinn Ito, KOF, EWN, and JST files are used as controls, robustness inputs, or exclusion checks, not as instruments.
Resource and commodity exposure	IMF commodity prices, real commodity prices, and natural resource rent variables are treated as confounder candidates because they can move credit and measured TFP directly.
Country specific micro files	Chilean Madeira files, Government Revenue, Maddison, WIID, and related auxiliary databases were reviewed but excluded from the main design because their coverage or object does not identify the cross country firm technology credit margin.

Notes: The replication package stores the full inventory in `results/data_inventory.csv`. The table reports the decision rule: variables are used in the main IV only when they help isolate predetermined demography or external sectoral credit reallocations. Variables that plausibly affect technology directly are used only as controls, diagnostics, or exclusions from the instrument set.