Customer capital and firm innovation*

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Abstract

This paper studies the interaction between customer capital and firm innovation. I develop a step-by-step innovation model where households form deep habits in consumption. These habits act as customer capital for firms: they can increase sales today, at a loss to current profits, to enjoy higher and more inelastic demand in the future. By changing future demand, customer capital affects firms' incentive to innovate. From data on public US firms, I find evidence of demand side effects. When a sector's outputs are consumed more by old households - those with stronger habits, the most productive firms in the sector increase their R&D investment relative to the others. I apply the model to quantify the effects of changes in aggregate customer capital arising from aging demographics. Under the model, the composition shift towards old households over the 1980-2019 period could account for over a quarter of the observed trends in increasing revenue productivity dispersion between firms, increasing concentration, and increasing aggregate markups. The model also shows how customer capital affects the outcomes of innovation policies. With customer capital, innovation subsidies have significantly larger impacts on concentration and markups, around three times as much as an environment without.

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1 Introduction

Customer capital is an important form of intangible capital for the firm. It is a main determinant of sales: differences in customer base account for around 80% of variance in sales across firms (Einav et al. 2021, Afrouzi et al. 2023). It contributes to higher familiarity and better perception of firm brand - a substantial portion of firm value[1]. Higher brand familiarity is associated with lower cash flow volatility and lower default risk (Larkin 2013). There is also empirical evidence that the desire to acquire and maintain customer capital drives firm decisions. Firms spend considerable amounts on advertisement and sales expenses. From surveys of firm price setting, one of the main reasons why firms keep price stable despite changing production costs is to maintain long-run relationships with customers (Blinder et al. 1998, Fabiani et al. 2006). Differences in consumption persistence across states drives differences in new firm formation (Bornstein 2021).

In this paper, I explore the interaction between customer capital and innovation, through three aspects. The first is at the individual level, how customer capital affects individual firm's incentives to innovate. The second is at the aggregate level, how changes in aggregate customer capital relate to trends in aggregate innovation and market concentration. I focus on changes induced by aging demographics, whereby older households with stronger customer capital effects accounts for more of aggregate demand. The third is how customer capital matters for government policy outcomes.

To explore this interaction, I develop a step-by-step model of innovation, incorporated with consumption habits. Consumption habits act as customer capital for firms, whereby if a firm increases their sales in the current period, they will enjoy higher and more inelastic demand in future periods. Through a simplified version of the model, I show how this affects the firm's incentives to innovate. A key object of my model is the strength of consumption habits, and I discipline it with empirical estimates regarding the evolution of brand preferences from Bronnenberg et al. (2012). I provide empirical support for my model using variations in age composition of demand within industries as a proxy for the strength of customer capital. I then apply the model to quantify the effect of aging demographics. Through the lens of the model, the induced rise in the share of older households in aggregate demand can account for a quarter of the increase in divergence of Research and Development (R&D) spending across firms, the increase in revenue productivity across firms, and the rise in aggregate markups and industry concentration. Finally, I consider the impact of government innovation subsidies, in the model and in an environment without customer capital as comparison. I find that when the effects of customer capital are incorporated, innovation subsidies have larger

[1] Belo et al. (2022) estimates brand capital to be 6-25% of firm market value

impacts on productivity dispersion, markups, and industry concentration - around 3 times as much as in the environment without customer capital.

My model builds on the step-by-step innovation framework of Aghion et al. (2001). There are many industries in the economy, and in each industry two dominant firms compete against one another. Take as example the beer industry, with AB Inbev producing Bud Light and Molson Coors producing Miller Light. Each period, I assume AB Inbev sets the quantity of Bud to sell, taking Molson Coors' strategies as given, and vice versa for Molson Coors (ie. Cournot competition). The firms can invest in R&D to reduce their future production costs, to set lower prices and capture more of the market. I add to this framework consumption habit formation, whereby the more households spend on a good, the more their future preference for the good increases. This implies that if AB Inbev increases their sales in the current period, they will enjoy higher and more inelastic demand in future periods. Consumption habit builds and depreciates slowly over time, and acts as customer capital for the firms. They can invest in this capital by increasing production, at a cost to their current profits, in order to gain higher profits in the future.

I begin with a simplified version of the model to understand how the increase in demand and decrease in demand elasticity arising from higher customer capital affect firm innovation. The two demand effects have opposing consequences for firm innovation. Higher demand incentivizes the firm to raise supply, which increases the incentive to innovate to reduce cost. Lower demand elasticity incentivizes the firm to restrict supply in favor of charging higher markups, which decreases the incentive to innovate. Which effect dominates depend on how large the firm's revenue productivity is compared to its rival. Evaluating the condition in the simplified version under plausible parameters and comparing to the level of revenue productivity dispersion in the data, the model suggests that higher customer capital would generally increase firm innovation.

I then set up the full model. On the household side, there are two types of households, young and old, that differ in the strength of their consumption habits. This heterogeneity is motivated by evidence in Bornstein (2021)[2], and propagates the effect of aging demographics. Specifically, I assume that only old households form habits, thus loading all customer capital effects on old households. Habits are exogenous to any individual household, and are determined by past expenditures by the average old household in the economy. On the firm side, in each industry, in addition to the two dominant firms, there is a mass of fringe firms. These fringe firms do not innovate, do not build customer

[2]Bornstein (2021) provides evidence that households above 35 years hold have significantly higher consumption persistence. This can be interpreted as older households having stronger customer capital effects, whereby past consumption matters more for current consumption, conditional on price and quality.

capital, and charge constant markups. The addition of the fringe generates flexibility for the model to match empirical levels of industry concentration and markups. The model also allows for entry and exit of duopolists: In each industry each period, a potential entrant conducts R&D. They enter if they successfully innovate, replacing the lower productivity firm and inheriting their stock of customer capital.

A key parameter in the model is the strength of consumption habits, and I discipline it based on empirical estimates from Bronnenberg et al. (2012). Their paper studies how migrants' consumption patterns evolve as they move from one market to another. A migrant's consumption would be similar to the average in their origin market, prior to moving, and it would be similar to the average in their destination market, after a sufficient period of time. How much their consumption changes in the period right after they move would then inform the strength of consumption habits. This setup is analogous to a movement from one long-run market state to another when goods price or quality changes, and I replicate it in the model to pin down the strength of consumption habits.

I turn to the data for empirical support for the model. Firm level customer capital is difficult to measure. Instead I focus on how the strength of customer capital affects innovation at the industry level. The strength of customer capital is also difficult to measure directly, and I proxy for it using the expenditure share of older households within an industry. When the expenditure share of older consumers within an industry is high, it implies increased demand and decreased elasticity for the more productive firms, as they can sell to more older consumers who would over time build habits for their products. Whereby for the less productive firms, it implies decreased demand, from less younger consumers that have not built habits for the more productive firm's good. A rise in the expenditure share of older consumers is similar to an increase in customer capital for the more productive firms, and a decrease in customer capital for the less productive firms. The simple model predicts, given the amount of revenue productivity dispersion in the data, an increased divergence in innovation between high and low productivity firms, and with it, an increase in productivity dispersion.

The data supports this prediction. I construct an industry panel, with a measure of older consumer shares in an industry from the Consumer Expenditure Survey, and industry R&D difference and productivity dispersion from public firms. Projecting R&D difference and change in productivity dispersion on the older consumer share, I find that higher share from older consumers is associated with larger R&D difference and more positive change in dispersion.

I first apply the model to quantify the effect of changes in aggregate customer capital, induced by aging demographics. Aging demographics increases the share of old households in the economy, which increases the strength of customer capital in the aggregate. I evaluate this in two ways, a comparison of balanced growth paths (BGPs), and changes along the transition from one BGP to another. For the BGP comparison, I start with a baseline economy calibrated to the US in the late 1970s, and compare it to an economy where the share of old households takes the value of that in the late 2010s. The higher old household share induces more productive firms to increase innovation compared to their competitors. This results in higher productivity dispersion, higher concentration, and higher aggregate markups, around 110%, 60%, and 50%, respectively, of the increases observed in the data over 1980 to 2020. Aging demographics is a slow process, there could be concerns about the speed of transition. Moreover, the share of old households is expected to continue to rise in the future. For this, I assume that the economy starts from a BGP in 1970, feed in the path of the share of old households forcasted until 2060, and calculate the transition to a new BGP. Effects along the transition are quantitatively smaller than the BGP comparison, due to the slow transition. From 1980 to 2020, the model generates increases productivity dispersion, concentration, and aggregate markups that is around 25%, 40%, and 30%, respectively, of the increases observed in the data over this period.

I then use the model to analyze how the inclusion of customer capital affects the outcome of government innovation policies. I consider two policies, a subsidy to entry and a subsidy to R&D. Firms in the model under invest in innovation, motivating the desire for such policies. Moreover, entry subsidies and R&D subsidies are widely used in practice. In the model, these two amount to decreasing the cost of innovation for potential entrants and incumbent firms respectively. They have some opposing outcomes: the subsidy to entry decreases productivity dispersion, concentration, and markups, and increases entry, while the subsidy to R&D increases productivity dispersion, concentration, and markups, and decreases entry. Compared to an environment without customer capital, the effect of these two policies on productivity dispersion, concentration, and markups is around 3 times as large. This arises from the interaction between customer capital and firm innovation decisions. For example, consider the subsidy to R&D, which increases innovation for both the leader - the more productive firm - and follower proportionally. This raises the absolute difference in the innovation rates, so that over time the gap in productivity widens and leaders become even more productive compared to their competitor. They then are able to capture more market share and build up more customer capital. Higher customer capital for the leader in return increases its incentive to innovate. This feedback effect amplifies the impact of innovation policies on the market structure.

Related Literature

This paper contributes to literature on the effect of customer capital for firms. Theoretically, industrial organization papers have studied how customer capital, arising through lock-ins and switching costs, affects market competitiveness. For example, Beggs and Klemperer (1992) shows how lock-ins result in decreased competitiveness, increased price markups and profits; Dube et al. (2009) shows that switching costs could instead increase competitiveness, depending on the size of the switching costs. In the macroeconomic context, Ravn et al. (2006) studies how the introduction of consumption habits affect firm cyclical behaviors in a dynamic stochastic general equilibrium model. Gourio and Rudanko (2014) studies customer capital that arises from frictional matching between consumers and producers, and its effect on firm investment, sales, markups, and responsiveness to shocks. On the empirical side, Larkin (2013) provides evidence on the effect of customer brand perception on firm finances, investments, and defaults. Baker et al. (2023) gives evidence on how customer churn is predictive of firm-level valuation. Afrouzi et al. (2023), and Einav et al. (2021) documents that differences in customer base among firms can account for 80% of the variance in firm sales. This paper contributes to this literature by studying the effect of customer capital on firm innovation decisions.

Customer capital is a form of intangible capital for firms, and recent papers have explored how intangibles affect innovation. De Ridder (2024) studies the consequences on production when firms are heterogeneous with respect to the efficiency of intangibles adoption. On the demand side, Shen (2023), Cavenaile and Roldan-Blanco (2021) and Cavenaile et al. (2024) explore how advertising interacts with firm innovation decisions. Customer capital is also a demand side channel, but unlike advertising in these papers, is a persistent state for firms that evolves dynamically through the firm's past sales. The treatment of customer capital in my paper is most similar to Ignaszak and Sedlacek (2023). While the framework in Ignaszak and Sedlacek (2023) deals with monopolistic firms, my paper incorporates a more complex competition structure. Accounting for competition is important for innovation (Aghion et al. 2001). It allows me to connect the outcomes of innovation to changes in the market structure. The competition structure also applies more closely to larger firms, who do the majority of R&D.

Other papers have studied the effect of aging demographic on firms. On the supply side, Hopenhayn et al. (2022) and Karahan et al. (2019) considers the effect of lower labor force growth rate, leading to a lower rate of new firm formation and older firms in the economy on average. Peters and Walsh (2021) furthers this argument in the the context of growth, where the decline in new firm formation results in lower creative destruction and innovation, leading to a decline in the aggregate growth rate. On the demand side, like this paper, Bornstein (2021) considers the affect of demographic shift through the channel customer capital. Whereas the main focus of Bornstein (2021) is firm pricing decisions, this paper emphasizes the effect on firm innovation incentives.

The model in this paper augments the step-by-step innovation framework from Aghion et al. (2001) with customer capital in the form of consumption habits. Recent papers have applied the framework to study innovation differences across firms. Akcigit and Ates (2023) explores the effect of lower rate of knowledge diffusion, Liu et al. (2022) studies the impact of lower interest rates, and Olmstead-Rumsey (2022) considers the consequences of declining innovative efficiency from smaller firms. Changes in customer capital arising from aging demographics, as in this paper, generates similar empirical observations. However, the inclusion of customer capital have different implication for government growth policies.

2 Simple model of customer capital and innovation

I setup a simple model to understand how changes in customer capital affects firm innovation decisions. The model gives intuition for the mechanism of the quantitative model in section 3.

2.1 Setup

Consider a duopoly industry with 2 periods. In the first period, firms make R&D investment decisions that affect their second period productivity. Production then occurs in the second period, whereby the firms compete ala Cournot.

Firm i in period 1 has productivity q_{i1}. They can invest in R&D to increase their productivity in period 2 probabilistically by a factor of λ. That is, their productivity in period 2, q_{i2}, is λq_{i1} with probability ι_{i1}, and q_{i1} with probability $1-\iota_{i1}$. To achieve a success probability of ι_{i1}, the firm has to spend $\frac{\gamma}{2}\iota_{i1}^2$.

In period 2, the firm produces with constant marginal cost $\frac{1}{q_{i2}}$. They face inverse demand

$$p_{i2} = \frac{\left(k_{i2}\right)^{\theta/\rho} c_{i2}^{-1/\rho}}{\left(k_{i2}\right)^{\theta/\rho} c_{i2}^{\frac{\rho-1}{\rho}} + \left(k_{-i2}\right)^{\theta/\rho} c_{-i2}^{\frac{\rho-1}{\rho}}},$$

where p_{i2} is the price that the firm faces, (c_{i2}, c_{-i2}) are the amount of goods produced by the firm and its competitor, and (k_{i2}, k_{-i2}) are predetermined customer capital stocks of the firm and its competitor. ρ determines the substitutability between the two goods, and θ determines how much customer capital matter for demand. This inverse demand could arise from consumers with CES preferences over the goods, or from aggregation of consumers making discrete choice decisions. (k_{i2}, k_{-i2}) akins to consumer liking the good more. How it evolves over time matters. I give a brief discussion at the end of this section, and I model it in more detail in the quantitative section.

The following proposition characterizes the second period payoffs and first period R&D decisions. All derivations are relegated to the Appendix.

Proposition 1. *For the 2 period industry duopoly,*

a) Second period payoff π_i *is given by*

$$\pi_i\left(k_{i2}/k_{-i2}, q_{i2}/q_{-i2}\right) = \frac{\left(\frac{k_{i2}^{\theta/\rho}}{k_{-i2}^{\theta/\rho}}\left(\frac{q_{i2}}{q_{-i2}}\right)^{(\rho-1)/\rho} + \frac{1}{\rho}\right)\frac{k_{i2}^{\theta/\rho}}{k_{-i2}^{\theta/\rho}}\left(\frac{q_{i2}}{q_{-i2}}\right)^{(\rho-1)/\rho}}{\left[1 + \frac{k_{i2}^{\theta/\rho}}{k_{-i2}^{\theta/\rho}}\left(\frac{q_{i2}}{q_{-i2}}\right)^{(\rho-1)/\rho}\right]^2};$$

b) For small $(\iota_{i1}, \iota_{-i1})$*, first period R&D decision* ι_{i1} *is approximated by*

$$\iota_{i1} = \frac{1}{\gamma}\left[\pi_2\left(k_{i2}/k_{-i2}, \lambda q_{i1}/q_{-i1}\right) - \pi_2\left(k_{i2}/k_{-i2}, q_{i1}/q_{-i1}\right)\right].$$

R&D choice ι_{i1} is determined by the amount gained in second period payoff π_i from increasing productivity. The customer capital stocks (k_{i2}, k_{-i2}) affect this gain, hence affect R&D choice.

2.2 Response of innovation to changes in customer capital

Consider the effect of changes in the customer capital stocks (k_{i2}, k_{-i2}) and changes in the strength of customer capital stocks θ on R&D decisions $(\iota_{i1}, \iota_{-i1})$. This can be thought of comparing the outcomes of a model with customer capital and one without ($\theta > 0$ vs $\theta = 0$), or changes in the model environment that facilitates higher capital stocks like in the case of aging demographics.

Define m_i such that $\frac{q_{i1}}{q_{-i1}} = \lambda^{m_i}$. Let $\kappa_i \equiv \left(\frac{k_{i2}}{k_{-i2}}\right)^{\theta}$, which encapsulates the customer capital effect, and redefine second period profits in terms of m_i, κ_i. First period R&D decision can be written as

$$\iota_{i1} = \frac{1}{\gamma} \int_0^1 \frac{\partial \pi_2 \left(\kappa_i, m_i + \epsilon\right)}{\partial \left(m_i + \epsilon\right)} d\epsilon.$$

We can sign the response of ι_{i1} to changes in customer capital by evaluating $\frac{\partial^2 \pi_2(\kappa_i, m_i)}{\partial m_i \partial \kappa_i}$. This is given in the following proposition.

Proposition 2. $\frac{\partial^2 \pi_2(\kappa_i, m_i)}{\partial m_i \partial \kappa_i} > 0$ *iff*

$$\kappa_i^{1/\rho} \lambda^{m_i(\rho-1)/\rho} < \sqrt{4\left(1 - \frac{1}{\rho}\right)^2 \left(2 - \frac{1}{\rho}\right)^{-2} + \frac{1}{\rho}} + 2\left(1 - \frac{1}{\rho}\right)\left(2 - \frac{1}{\rho}\right)^{-1}.$$

The term on the left hand side is the ratio of revenue productivity between firm i and its competitor. The term on the right hand side is a function only of the substitution parameter ρ. For ρ as low as 2, it takes a value of around 1.64; and ρ approaches ∞, the term approaches a value of 2. Proposition 2 implies that an increase in the customer capital effect for firm i could either increase or decrease innovation, depending on the ratio of revenue productivity with its competitor. Intuitively, this is because an increase in the customer capital effect both raises demand and reduces demand elasticity, resulting in competing effects on innovation incentives. Higher demand incentivize the firm to innovate to reduce the cost of higher production. Lower elasticity incentivize the firm to reduce production to increase markups, reducing the incentive to innovate.

We can examine the firm and its competitor jointly to characterize productivity dispersion and industry markups. I focus on the case where the leader - the firm with higher productivity - increases its innovation in response to an increase in its customer capital. Suppose that firm i has higher productivity and revenue productivity than its competitor, but smaller than the threshold in Proposition 2. An increase in κ_i then increase ι_{i1}. For the competitor, firm $-i$, κ_{-i} decreases. Moreover, $\kappa_{-i}^{1/\rho} \lambda^{m_{-i}(\rho-1)/\rho} < 1$ as firm $-i$ has lower revenue productivity, so ι_{-i1} decreases. Now the expected change in the standard deviation of log productivity from period 1 to period 2 is proportional to the difference in innovation rates, $\iota_{i1} - \iota_{-i1}$. That is, expected productivity dispersion increases if the more productive firm innovates more than the less productive firm. As ι_{i1} increases and ι_{-i1} decreases following the increase in κ_i, expected productivity dispersion increases. Expected revenue productivity dispersion increases, both directly from the higher κ_i and indirectly from it increasing productivity dispersion.

There are feedback effects that strengthen the interaction between customer capital and firm innovation once we extend the model to multiple periods. For simplicity, consider repeating the two period game many times, keeping firm payoffs and policies fixed but updating their productivities and customer capital. Productivities in period 1 are inherited from the previous period 2, and customer capital evolves as an increasing function of past market share. Now the more productive firm will produce more and have higher market share, which increases their future customer capital. Higher customer capital in turn incentivize the more productive firm to innovate more, increasing its productivity in future periods.

The model have implications for the effect of aging demographics. Under the assumption that older households have stronger customer capital effects, aging demographics generates stronger overall customer capital effect for firms, as well as facilitates higher capital stocks as their consumers live longer. This is captured by an increase in κ_i for the more productive firm: it sees an increase in demand from the larger pool of older households that have stronger customer capital effects, along with more inelastic demand; whereas its competitor sees a decrease in demand from the smaller pool of young households with weaker customer capital effects. Moreover, we expect the more productive firm to increase its innovation in response: from the data for public US firms, the standard deviation of log revenue productivity is 0.22, while the threshold of $\log\left(\kappa_i^{1/\rho}\lambda^{m_i(\rho-1)/\rho}\right)$ for reasonable parameters is 0.66. Aging demographics would then result in increases in divergence of R&D between high and low productivity firms and increases in productivity dispersion.

The model have implications for the response of firms to government R&D policies. Consider a decrease in the cost of R&D γ, stemming from an R&D subsidy. This increases both the leading firm and the following firm innovation rates proportionally. The difference in innovation rates, $\iota_{i1} - \iota_{-i1}$, also changes proportionally, and productivity dispersion increases if this was originally positive. The addition of customer capital entails a feedback effect, where increased dispersion raises customer capital for the leading firm, prompting it to do more R&D and furthering its lead over time. This feedback effect amplifies the effect of growth policies on the market structure.

3 A model of consumption habits and firm innovation

In this section, I develop a model of innovation with customer capital that arise through consumption habits. The model builds on the step-by-step innovation framework of Aghion et al. (2001), where there are two dominant firms in each industry engage in a race in innovation to be the market leader. Additionally, firms accumulate consumer habits for their products (Ravn et al. 2006). These habits boost the firm's demand, and is built from past household consumption. Households stochastically age and stochastically die, and the rate of aging and rate of death determine the share of older households in the economy. For the baseline results, I model the demographic shift as decreasing the probability of death, which effectively raises the share of older households in the economy.

3.1 Environment

3.1.1 Households

There are two types of households in the economy, young and old, with a total mass of 1. Each period, a random portion ϵ_1 of young households turn old, a random portion ϵ_2 of old households leave the economy, and new young households enter the economy. The mass of entering young household is the same as the mass of leaving old households. Denote the mass of young and old households by M_y and M_o respectively.

Households discount the future at rate β. Their period preferences are given by

$$U_t^a = \ln C_t^a - L_t^a,$$

where $a \in \{Y, O\}$ denotes household type, C_t^a is a consumption aggregator over sectoral goods, $C_t^a = \exp\left[\int \ln C_{jt}^a dj\right]$, and L_t^a is the household's labor supply. Their budget constraint is

$$P_t^a C_t^a + P_t^A A_{t+1}^a = L_t^a + \left(P_t^A + d_t\right) A_t^a,$$

where A_t^a is a claim to a bundle of all firms in the economy, P_t^a is the price index on aggregated consumption, P_t^A is the price of the firm bundle, and d_t is the bundle's dividend payout. I normalize the wage to 1. The price index on aggregated consumption is allowed to differ by household types: while households face the same price for individual goods, differences in their habits will lead to different price indexes.

In each sector, there is a pair of duopolist along with a fringe producing imperfectly substitutable goods. The sectoral good is given by the aggregator

$$C_{jt}^Y = \left(0.5^{\frac{-\theta}{\rho}} \left[0.5^{\frac{\theta}{\rho}} \left(C_{1jt}^Y\right)^{\frac{\rho-1}{\rho}} + 0.5^{\frac{\theta}{\rho}} \left(C_{2jt}^Y\right)^{\frac{\rho-1}{\rho}} + 0.5^{\frac{\theta}{\rho}} \int^{\mathcal{N}} C_{fjt}^Y(x)^{\frac{\rho-1}{\rho}} dx\right]\right)^{\frac{\rho}{\rho-1}}$$

$$C_{jt}^O = \left(0.5^{\frac{-\theta}{\rho}} \left[k_{1jt}^{\frac{\theta}{\rho}} \left(C_{1jt}^O\right)^{\frac{\rho-1}{\rho}} + k_{2jt}^{\frac{\theta}{\rho}} \left(C_{2jt}^O\right)^{\frac{\rho-1}{\rho}} + 0.5^{\frac{\theta}{\rho}} \int^{\mathcal{N}} C_{fjt}^O(x)^{\frac{\rho-1}{\rho}} dx\right]\right)^{\frac{\rho}{\rho-1}},$$

where $\mathcal{N}$ is the (exogenous) mass of fringe firms, and ρ determines how substitutable goods within the sector are. Households' utility for consuming each firm's good is affected by their habit stock, with the strength of this effect governed by θ. Young households have equal habit stocks, constant at 0.5, across all goods. As such, consumption habits do not affect young households. Old households' habit stocks for goods produced by duopolists, k_{1jt} and k_{2jt}, are determined based on past expenditure on these goods. I assume that these habits are external: they are determined by the average expenditure of other old households, so that a household's own consumption does not affect their habit stock. Habit stocks evolve according to

$$\begin{aligned} k_{ijt+1} = (1-\delta)\, & \frac{0.5\epsilon_1 M_y + k_{ijt} M_o (1-\epsilon_2)}{\epsilon_1 M_y + M_o (1-\epsilon_2)} \\ & + \delta \frac{\frac{p_{ijt} C^y_{ijt}}{p_{ijt} C^y_{ijt} + p_{-ijt} C^y_{-ijt}} \epsilon_1 M_y + \frac{p_{ijt} C^o_{ijt}}{p_{ijt} C^o_{ijt} + p_{-ijt} C^o_{-ijt}} M_o (1-\epsilon_2)}{\epsilon_1 M_y + M_o (1-\epsilon_2)}. \end{aligned} \tag{1}$$

The first term represents the average habit stock for old households in period t, taken as the weighted average of habit stocks from young households that newly turned old -which takes a value of 0.5, and habit stocks of surviving old households - which takes a value of k_{ijt}. The second term represents the average expenditure on the good relative to spending on duopolist goods, for old households, in period $t-1$. δ determines the speed at which customer capital changes. I assume that given starting stocks k_{ij0}, k_{-ij0} is such that $k_{ij0} + k_{-ij0} = 1$, hence we have $k_{ijt} + k_{-ijt} = 1\ \forall t$. Firm i with $k_{ijt} > 0.5$ is then the firm with larger customer capital stock in the sector, and $k_{ijt} = 0.5$ represents a neutral level of customer capital, which I set the level of young household's stock to.

3.1.2 Firms

In each sector, firms engage in Cournot competition. Production technology is given by

$$Y_{ijt} = q_{ijt} l_{ijt},$$

where $Y_{ijt}, q_{ijt}, l_{ijt}$ is the firm's goods output, productivity, and labor input. Firm demand is given by summing up demand across households:

$$C_{ijt} = \left(C^Y_{ijt} M_y + C^O_{ijt} M_o \right).$$

Firms can invest in R&D to improve productivity probabilistically. To achieve a R&D success probability of ι_{ijt}, the firm has to employ $\frac{\gamma}{2}\left(\log\left(\frac{1}{1-\iota_{ijt}}\right)\right)^2$ units of labor in R&D. Let D_{ijt} be an indicator function for R&D success. The firm's increase in productivity when $D_{ijt}=1$ differs whether the firm is a leader or a follower in the sector. I refer to the firm with the higher productivity, or higher customer capital in the case of equal productivity, as the leader, and denote variables associated with . Variables associated with the follower are denoted with .

For the leader, productivity increases proportionally by a factor $\lambda > 1$, so that

$$\overline{q}_{jt+1} = \overline{D}_{jt}\lambda\overline{q}_{jt} + \left(1-\overline{D}_{jt}\right)\overline{q}_{jt}.$$

The follower has an additional chance of achieving a breakthrough with each successful innovation, effectively catching up to the leader's technology level from the previous period:

$$\underline{q}_{jt+1} = \underline{D}_{jt}\left(1-\Phi\right)\lambda\underline{q}_{jt} + \underbrace{\underline{D}_{jt}\Phi\overline{q}_{jt}}_{\text{Closing the gap}} + \left(1-\underline{D}_{jt}\right)\underline{q}_{jt},$$

where $\Phi = 1$ with probability ϕ.

Let m_{ijt} be such that $\lambda^{m_{ijt}} = \frac{q_{ijt}}{q_{-ijt}}$. m_{ijt} encodes the relative productivity between firm i and its rival in sector j, which I refer to as the technology gap. Assuming that $q_{ij0} = 1 \quad \forall i, j$, m_{ijt} is integer valued. Moreover, assume that there is a maximal gap $\bar{m}$ such that $\bar{m} \geq m_{ijt} \geq -\bar{m}$.

Fringe firms do not innovate. I assume that their technology level is a weighted geometric average of the follower and leader in their sector: $q_{fjt} = \left(\overline{q}_{jt}\right)^{\alpha}\left(\underline{q}_{jt}\right)^{1-\alpha}$.

There is a prospective entrant in each sector each period. The prospective entrant conducts R&D, ι^e_{jt}, to innovate on top of the follower's technology. Their prospective technology is such that

$$q^e_{jt+1} = D^e_{jt}\left(1-\Phi^e\right)\lambda\underline{q}_{jt} + D^e_{jt}\Phi^e\overline{q}_{jt} + \left(1-D^e_{jt}\right)\underline{q}_{jt},$$

where $D^e_{jt} = 1$ with probability ι^e_{jt} and $\Phi^e = 1$ with probability ϕ. They enter next period if their innovation is successful, and that their technology is higher than the follower's. They then replace the replace the follower in that sector and inherits their habit stock.

The timing within a period is as follows. The duopolists first simultaneously set quantities. Fringe firms then set their quantities. Incumbents and entrants proceeds to set their innovation rates. Afterwards, firms realize their profits and pay wages to their workers. Finally, the outcomes of innovation and entry are realized.

3.2 Characterization and equilibrium

3.2.1 Households

In equilibrium, it can be shown that young households are on their Euler equation for firm bundles, while old households do not firm bundles. Firms then discount at rate β. As a result, changes in the death rate ϵ_2, to model aging demographics, do not the firm discount rate. This isolates the effect of aging demographics that operates through consumer habits, as opposed to effects that operate through the interest rate.

With the given preference structure, demand for duopolist good ij at time t for an individual household, conditional on their habit stocks $\{k_{1jt}, k_{2jt}\}$, is

$$C_{ijt}^{Y} = \frac{p_{ijt}^{-\rho}}{p_{ijt}^{1-\rho} + p_{-ijt}^{1-\rho} + \int^{\mathcal{N}} p_{fjt}\left(x\right)^{1-\rho} dx}$$

$$C_{ijt}^{O} = \frac{\left(k_{ijt}\right)^{\theta} p_{ijt}^{-\rho}}{\left(k_{ijt}\right)^{\theta} p_{-ijt}^{1-\rho} + \left(k_{-ijt}\right)^{\theta} p_{-ijt}^{1-\rho} + \left(0.5\right)^{\theta} \int^{\mathcal{N}} p_{fjt}\left(x\right)^{1-\rho} dx}.$$

Moreover, the sectoral expenditure is $p_{jt}C_{jt} = 1$. Note that demand for good i in sector j only depends on prices of goods in that sector, and not on the aggregate price. This results from the assumption of linear labor disutility combined with the outer nest elasticity of 1.

3.2.2 Firms

Fringe firms cannot affect their elasticity of demand. They charge a fix markup over their marginal cost, setting price as $p_{fjt}\left(x\right) = \frac{1}{q_{fjt}} \frac{\rho}{\rho-1}$.

Duopolists can affect their demand and demand elasticity, through the quantity that they currently produce and through their customer capital. Duopolist profit is given by

$$\pi_{ijt} = p_{ijt}C_{ijt} - l_{ijt} = s_{ijt} - l_{ijt},$$

where I have defined $s_{ijt} \equiv p_{ijt}C_{ijt}$. Since sectoral expenditure $p_{jt}C_{jt} = 1$, s_{ijt} is also the expenditure share of good ij in sector j at time t. As firms compete in quantities, their choice variable is effectively l_{ijt}. (s_{ijt}, s_{-ijt}) can be solved as an implicit function of l_{ijt} and l_{-ijt}, along with the productivity gap m_{ijt} between the duopolists.

The problem of a duopolist can be written as

$$v_t\left(k, k_-, m\right) = \max_{l, \iota} s_t\left(l, l_-, k, k_-, m\right) - l - \frac{\gamma}{2}\left(\log\left(\frac{1}{1-\iota}\right)\right)^2 \\ + \beta E_{m', \mathcal{R}}\left[v_{t+1}\left(k', k'_-, m'\right)\left(1-\mathcal{R}\right)\right] \tag{2}$$

with k', k'_- evolving according to equation (1). $\mathcal{R}$ is an indicator for if the firm is replaced by the entrant.

3.2.3 Equilibrium

I consider the recursive equilibrium on the balanced growth path (BGP) of the economy, where household mass M_y, M_o are constant, aggregate consumption C^Y, C^O grow at a constant rate, and the distribution of sectors is stationary. Formally, the recursive equilibrium on the BGP consists of household policies $\left\{C^Y\left(k, k_-, m\right), C^O\left(k, k_-, m\right), A^Y, A^O, L^Y, L^O\right\}$, firm policies $\left\{l\left(k, k_-, m\right), \iota\left(k, k_-, m\right), \iota^e\left(k, k_-, m\right)\right\}$, firm value $v\left(k, k_-, m\right)$, distribution of sectors $\Omega\left(k, k_-, m\right)$, law of motion Γ for $\Omega\left(k, k_-, m\right)$, and (relative) prices $\left\{P^A, \frac{p_-}{p}\left(k, k_-, m\right), \frac{p_f}{p}\left(k, k_-, m\right)\right\}$, such that

1. $\left\{C^Y\left(k, k_-, m\right), C^O\left(k, k_-, m\right), A^Y, A^O, L^Y, L^O\right\}$ solves the household problem, given prices
2. Given competitor's policies $\left\{l\left(k, k_-, m\right), \iota\left(k, k_-, m\right), \iota^e\left(k, k_-, m\right)\right\}$, the firm value $v\left(k, k_-, m\right)$ is consistent with the firm Bellman equation (2), and firm policies $\left\{l\left(k, k_-, m\right), \iota\left(k, k_-, m\right), \iota^e\left(k, k_-, m\right)\right\}$ are consistent with maximization
3. P^A clears the asset market
4. Relative prices $\left\{\frac{p_-}{p}\left(k, k_-, m\right), \frac{p_f}{p}\left(k, k_-, m\right)\right\}$ clears the goods market for each sector
5. The distribution of sectors $\Omega\left(k, k_-, m\right)$ is stationary, and its law of motion, Γ, is consistent with firm policies: For all sets S in the Borel algebra of the domain of Ω, and for all states $\left(k, k_-, m\right)$ with $k + k_- = 1$,

$$\Omega\left(S\right) = \int \left\{1_{\left\{\left(k'\left(k, k_-, m\right), 1-k'\left(k, k_-, m\right), m\prime\right) \in S\right\}} Pr\left(m' | \iota\left(k, k_-, m\right), \iota\left(k_-, k, -m\right), \iota^e\left(k, k_-, m\right), m\right)\right\} d\Omega(k, k_-, m)$$

The equilibrium concept is standard, with the addition that duopolist behavior within a sector is strategic and constitutes a Markov Perfect Equilibrium.

3.3 Parameterization

The quantitative model has 11 parameters, $(\beta, \epsilon_1, \epsilon_2, \rho, \delta, \theta, \lambda, \gamma, \phi, \mathcal{N}, \alpha)$. I describe how each parameter is set. I use the model for two main exercises - quantifying the effect of changes in customer capital arising from aging demographics, and assessing the impact of customer capital on innovation policies. Here, I show the parameterization for the first exercise.

I first parameterize the model to correspond to targets for the US in the late 1970s. Table 1 summarizes this parameterization. One period in the model corresponds to a quarter. I set the discount rate β at 0.99. ϵ_1 is set at 0.0357, which implies that the average age of young households is 27, assuming households enter the economy at 20 years old. ϵ_2 is then set so that the population share of old households is 0.65, which is the average for the late 1970s.

I set ρ at 10. Coupled with the Cournot competition structure, the trade literature has shown that this generates empirically relevant cost pass through to prices (Amiti et al. 2019)[3]. I set $\mathcal{N}$, the mass of fringe firms, so that average market share of a duopolist firm in the model is 0.23. α, the weight on the leading firm's productivity in fringe productivity, is set to target an aggregate markup of 1.25.

γ, the cost of R&D, affects the success rate of R&D. As potential entrants only enter after R&D success, I set γ to target an entry rate of 3%. This entry rate corresponds to that of firms with 10 or more employees. λ, the innovation step size, can then be set to target a growth rate of 2.2%. I set ϕ, the probability of the less productive firm closing the gap after a successful innovation, to achieve 0.22 revenue productivity dispersion.

Param	Description	Value	Param	Description	Value
β	Discount rate	0.99	λ	Growth step size	1.085
ϵ_1	Prob. of turning old	0.0357	$\mathcal{N}$	Mass of fringe	3.7
ϵ_2	Prob. of death	0.0192	α	Fringe productivity weight	0.756
ρ	Sectoral elas. of substitution	10	γ	Cost of R&D	8.05
δ	Depreciation of consumer habit	0.0133	ϕ	Prob of closing gap, upon success	0.383
			θ	Strength of consumer habit	2.2

Table 1: Parameterization

I discipline θ and δ, the parameters governing the strength and depreciation of consumer habit, based on estimates from Bronnenberg et al. (2012). The authors leverage migration as a source of change in

[3]The cost pass through has a close relationship with how demand elasticity vary, which is important for the effect of customer capital as shown in the simple model

market conditions facing the individuals migrating, and track changes in their consumption patterns to inform the strength and depreciation of consumer habit. Consider two markets in different locations, A and B, with goods x and y as the two products with the highest market share in both markets. Define the relative share of good x, S^x_A and S^x_B in market A and B respectively, as the ratio of x's sales to the sum of x and y's sales in that market. The relative market shares could differ across markets[4]. Now take an individual i that migrates from A to B. Denote their relative expenditure on x at period t after migration by S^x_{it}. Before they migrate, their expenditure share on x, should look the same as others in market A, ie $S^x_{i0} = S^x_A$. Once they migrate, after a period of time, their expenditure share should look the same others as in market B, ie $\lim_{t\to\infty} S^x_{it} = S^x_B$. In the period right after they migrate, the extent to which S^x_{i1}, is similar to S^x_A as opposed to S^x_B will inform the strength of consumption habits. Define $G_t \equiv \frac{S^x_A - S^x_{it}}{S^x_A - S^x_B}$. If there was no consumption habit, we would expect S^x_{i1} to immediately be the same as long-time residents in B, so $G_1 = 1$. Whereas if consumption habits were perfectly rigid, we would have $G_1 = 0$. Moreover, the time it takes after migration for G_t to rise to 1 will inform the depreciation of consumption habits.

This setup is analogous to where market conditions changes within a single market. If we take A and B as long run market states, S^x_A and S^x_B would be long run relative market shares. Starting from A, suppose goods prices or qualities change such that the new long run state is B. Let S^x_{it} be the relative market share of x at period t after the change. The measure $G_t \equiv \frac{S^x_A - S^x_{it}}{S^x_A - S^x_B}$ could then be applied to discipline the strength and depreciation of habits.

I implement this in the model as follows. I start with a sector where duopolists have the same productivity, so $m = 0$. k is chosen such that it is greater than 0.5 and corresponds to the long run level of customer capital if m does not change. This is corresponds to market state A in the above setup. I then move m to 1, and set new prices according to equilibrium firm policies. This gives the new long run market state B. I can then track S^x_{it} and calculate the measure G_t as above. I target a G_1 of 0.68, so that 68% of the difference in long term expenditure shares is reached upon price change. The remaining 32% is closed in subsequent years, and I target a half-life of 9.62 years. This implies a value of δ at 0.0133.

Table 2 shows model moments under the parameterization, compared to their targets.

[4]This could be from, for example, relative price differences due to supply costs or regional contracts, or differences in accessibility of product.

Moment	Model	Target	Source
Revenue productivity dispersion	0.22	0.22	Compustat
Fraction of long term market share obtained upon price change	0.691	0.68	Bronnenberg et. al. (2012)
Aggregate markups	1.252	1.25	Compustat
Growth rate	2.19%	2.2%	SF Fed
Mean market share	0.228	0.23	Mongey (2021)
Entry rate	3.03%	3.0%	BDS

Table 2: Model moments

4 Empirical support for the model

I proxy for the strength of customer capital effects in an industry using the consumption share of older households within that industry. Using variations within industries over time, I find evidence that when the consumption share of older households is higher in an industry, there is larger divergence in R&D investment between the most productive firms and the rest for that industry. This supports the predictions from the simple model. I then run similar regressions on simulated data from the quantitative model, finding results of the same magnitude as the empirical regressions.

4.1 Effect of older households consumption share

The simple model predicts that changes to the firm's customer capital affects its spending on R&D. However, in the data, customer capital at the firm level is difficult to quantify. Instead, I take a step back and consider the strength of customer capital effects at the industry level, proxying for it using the consumption share of older households within an industry.

Bornstein 2021 documents that households above 35 significantly less likely to switch products than those younger. Using retail scanner data, under the assumption that product quality and price are constant across markets, the author exploits variations to identify product switching rates for various consumer age groups. This corresponds to the persistence of product consumption, after controlling for product quality and prices. Bornstein finds that households below 35 have significantly lower persistence compared to those above 35. This is true for a wide variety of product types.

The persistence in consumption can be interpreted as the strength of customer capital effects. Without customer capital effects, once quality and price are accounted for, there would be no persistence.

Persistence close to 1 implies strong customer capital effects, dwarfing considerations for quality and price. With persistence being larger for older households, when the consumption share of older households is larger, we could expect stronger customer capital effects on average for the industry. This motivates using the share as a proxy.

With the amount of revenue productivity dispersion in the data, the simple model predicts that stronger capital effects increases R&D spending for the most productive firms relative to the rest. Hence I examine how the consumption share comoves with R&D divergence. Greater divergence would imply more dispersion in productivity. I examine the comovement with productivity dispersion as well.

4.2 Data

I construct a panel data of industries from 1990 to 2019, with measures of the share of expenditures by older households, the innovation gap, and revenue productivity dispersion for each industry. Measures for the innovation gap and revenue productivity dispersion are constructed from public firms data (Compustat). The expenditure share is constructed from household data from the Consumer Expenditure Survey (CEX).

I first estimate revenue productivity for public firms. This allows me to separate firms within an industry into leaders - the most productive firms - and followers. I estimate firm revenue productivity via production function estimation, following the method in Flynn et al. (2019). I specify firms' production function as a flexible translog in capital and inputs, and allow the coefficients to vary with time and 2 digit industries. Details are provided in the appendix.

I define industries by their 3 digit NAICS codes, as various 4 digit NAICS industries in Compustat have few firms, leading to potentially large errors in constructed measures for revenue productivity dispersion and innovation gap. For revenue productivity dispersion, I use the standard deviation of revenue productivity of firms within the industry.

I construct various measures for the innovation gap. The simple model requires a measure of firm innovation probabilities, which is a transformation of firm R&D spending. I consider 4 transformations. The first is using R&D spending directly. The second is using $\log(\text{R\&D} + 1)$, to allow for convexity in innovation cost. The third and fourth are R&D spending per worker and $\log(\text{R\&D spending per worker} + 1)$. Though the model calls for innovation not scaled by size, the scaling is to alleviate concerns of firms taking on additional products. For each measure x, for each industry j, I calculate the mean of x for firms above the 90^{th} quantile of revenue productivity in that industry and firms below ($\bar{x}_j^2, \bar{x}_j^1$ respectively). The innovation gap is then $\bar{x}_j^2 - \bar{x}_j^1$.

The CEX reports household consumption by modules, along with household characteristics. I crosswalk CEX modules to NAICS industries, largely following the BLS. Details in the appendix. Following Bornstein (2021), I choose 35 as the age cutoff for older households[5]. For each industry, I use the expenditure of older households over total expenditures.

The consumer demographic mechanism mainly affects consumer goods. To focus on such industries, I restrict my panel to industries that produce a large fraction of output as final goods, defined by being above the median industry in the economy in fraction of output that are final goods. As I am concerned with longer run trends, I want take out short run fluctuations in revenue productivity, R&D spending, and expenditure composition. I divide the sample period into bins of 3 years, and taking average values across the 3 years for each bin[6].

4.3 Comovements with consumption share of older households

Consider first the relationship between the consumption from older households and the innovation gap. I run the following regression

$$Y_{jt} = \beta_0 + \beta_1 S_{jt} + \beta_2 A_{jt} + \alpha_j + \eta_t + \epsilon_{jt},$$

with j denoting industry, t denoting the 3-year period, $Y_{jt} = \bar{x}_{jt}^2 - \bar{x}_{jt}^1$ as the innovation gap, S_{jt} as the share of expenditures by older households, and A_{jt} as revenue productivity dispersion. Here β_1 is the main parameter of interest. I control for productivity dispersion as suggested by the simply model. I include industry and time period fixed effects. Results are given in Table 3.

The consumption share of older households comoves more positively with the innovation gap for higher productivity groups, when using either R&D, R&D per worker, $\log(\text{R\&D} + 1)$, or $\log(\text{R\&D per worker} + 1)$ as proxy for innovation. This corroborates with the prediction from the simple model.

Now consider the relationship between the consumption from older households and productivity dispersion. As customer capital affects the innovation gap, which in turn affects the evolution of productivity dispersion, I run the following regression

$$\Delta Disp_{jt} = \gamma_0 + \gamma_1 S_{jt-1} + \psi_j + \zeta_t + \varepsilon_{jt},$$

[5] similar for 50 as cutoff

[6] Results are similar when using 5 year bins instead

where $\Delta Disp_{jt}$ is the change in revenue productivity dispersion between 3-year period $t-1$ and 3-year period t. Results are in the last column of Table 3.

When the share of consumption by older households rises in an industry, that industry sees a more positive change in their log revenue productivity dispersion over a 3 year period.

Dep var	$R\&D_{jt}$	$\log(1+R\&D)_{jt}$	$R\&D/emp_{jt}$	$\log(1+R\&D/emp)_{jt}$	$\Delta sd\ \log(prod)_{jt+1}$
S_{jt}	310.15	14.45	115.60	12.17	0.75
	(1.08)	(1.99)	(1.97)	(2.76)	(2.59)
Industry FE	✓	✓	✓	✓	✓
N ind	28	28	28	28	28
N ind×time	224	224	221	221	258

Table 3: Consumption from older households, the Innovation gap, and Revenue productivity dispersion

4.4 Comparison to the quantitative model

	Simulated	Data	
R&D	4.11	8.54	8.47
		$(-0.49, 17.56)$	$(-7.35, 24.30)$
$\log(1+\text{R\&D})$	4.21	8.84	13.65
		$(1.40, 16.29)$	$(0.18, 27.13)$
FE	Ind	Ind	Ind, Time

Table 4: Regression coefficients, simulated and empirical

5 The effect of aging demographics

5.1 Comparing BGPs

To model the effect of demographic shift, I compare the model economy with the above parameterization to one where $\epsilon_2 = 0.0139$. This corresponds to the share of old households in the economy at 0.72, the average for the US in the 2010s. The results are shown in Table 5.

	Model		Data
Fraction of older households	0.65	0.72	
R&D difference	0.0172	+0.243 std	+0.491 std
Revenue productivity dispersion	0.22	+0.123	+0.113
Aggregate markups	1.252	+0.066	+0.11
Mean market share	0.228	+0.028	+0.05
Entry rate	3.03%	-0.8%	-1.28%
Growth rate	2.19%	+0.08%	-0.36%

Table 5: Comparing BGPs

5.2 On the transition

Comparing BPGs alone does not give the full picture. Aging demographics is a slow process, and the movement to a new BGP could be slow as well. Moreover, the degree of demographic aging extends beyond level in the 2010s, and forward looking firms take this into account. Here, I look at the transition from one BGP to another. I assume that the economy is initially on the BGP in 1970, with the parameters in subsection 3.3. I then feed in the path of ϵ_2 that generates the observed and projected path of share of older households to 2060, after which I assume ϵ_2 to stablise.

Figure 1 shows the result of this transition, for the years 1980 to 2060. Panel a shows the realized and projected path of the share of older households in the economy. Panel b shows the evolution of revenue productivity dispersion. It increases slowly, and is expected to continue to increase. This is the case for aggregate markups, panel c, and mean market share, panel d, as well.

Table 6 shows the changes from 1980 to 2020 implied by the transition. The slow evolution of revenue productivity dispersion along the transition implies a smaller effect of aging demographics compared to the BGP comparison. The closest is mean market share, whereby the firms expand relatively fast along the transition in order to capture aging consumers. Entry rate also decreases similar in magnitude to the BGP comparison.

6 Response of firms to government policies

The section above suggests a quantitative importance of interaction between customer capital and innovation. In this section, I consider how firm response to government policies can differ once

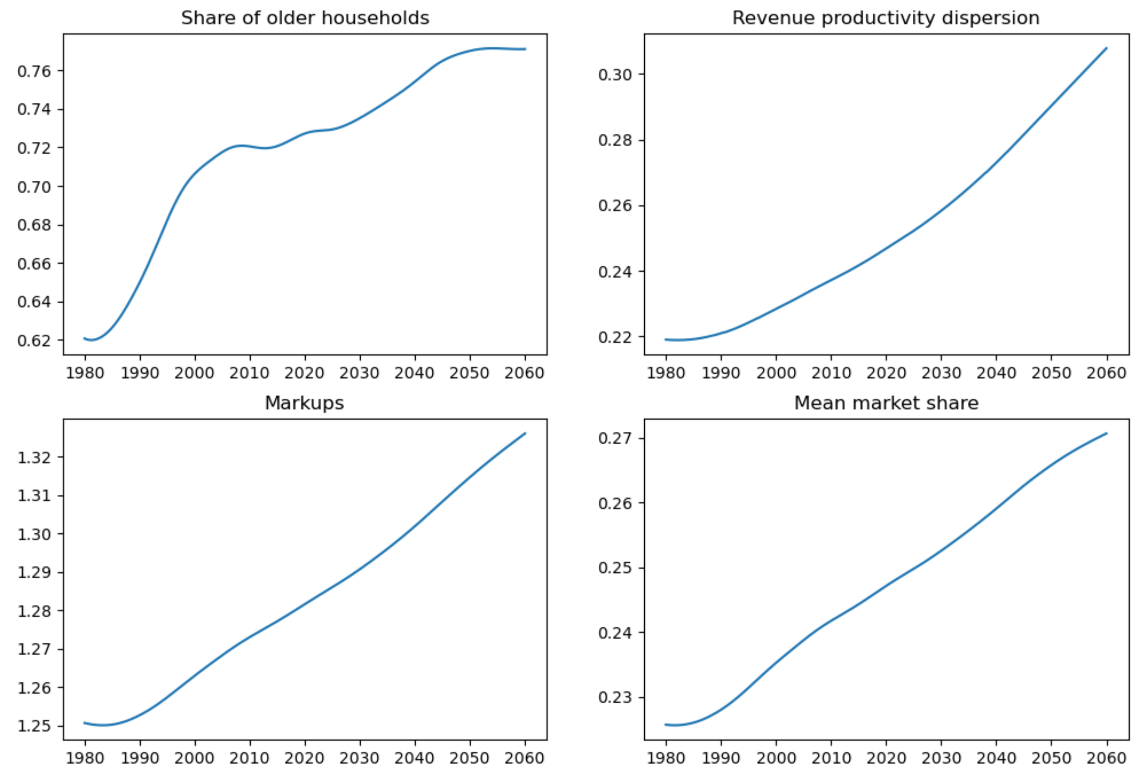

Figure 1: Transition

customer capital is accounted for. I first discuss the inefficiencies associated with the model environment, to highlight how the government could pursue policies to improve upon the equilibrium. I then consider 2 innovation policies: a subsidy to entry, and subsidy to R&D. The 2 policies are widely used, as different means of raising innovation rate. For each policy, I also compare its effect to an environment without customer capital. I recalibrate both environments to targets in the late 2010s.

6.1 Welfare and market inefficiencies

Define social welfare as integral over all of household utility. This requires valuation of future "unborn" households. I assume that the discount rate for future generations is the same as the household time discount rate, β. For a planner that maximizes social welfare, they choose the amount supplied of each good, along with innovation rates for each dominant firm and potential

Year	Model		Data
	1980	2020	1980-2020 change
R&D difference	0.0185	+0.212 std	+0.491 std
Revenue productivity dispersion	0.219	+0.028	+0.113
Aggregate markups	1.251	+0.031	+0.11
Mean market share	0.226	+0.021	+0.05
Entry rate	3.0%	-0.89%	-1.28%

Table 6: Transition

entrant. They face the same law of motion for habits as in the market equilibrium, along with the same allocation of goods among young and old household for each amount supplied as in the market equilibrium.

The planning solution differ from the market equilibrium in both amount of good supplied and innovation rates. Regarding supply, duopolists in most cases restrict supply and charge markups. As for innovation rates, the payoff of innovating form the firm differs from the planner in two ways. First, the per-period gains differ, as firms only consider the gains to profits while the planner also considers the gains to consumers. These gains are generally larger for the planner. Second, while the planner enjoys the gains from better technology forever, the firm only has it until its rival or potential entrant innovates. In most cases, this results in under investment in innovation.

This leaves room for the government to improve upon the market allocations. For example, the government can utilize a mixture of targeted production subsidy to induce higher production, along with targeted R&D subsidy to induce higher innovation. This applies to both the environments with and without customer capital.

6.2 Entry subsidy and R&D subsidy

I consider the effects of a subsidy to entry and a subsidy to R&D cost. The subsidies are meant to induce higher innovation, with the former for entrant innovation and the latter for incumbent innovation. These subsidies are untargeted, in that firms with different productivity gaps and different levels of customer capital receive same proportional subsidy. I enact a 10% subsidy to potential entrants' cost of innovation, and 10% subsidy to incumbent cost of innovation respectively. Each policy is funded by lump-sum taxes on households. For the results, welfare is calculated from 1st period when policy is announced and enacted, along the transition[7]. Other statistics are calculated on the BGP.

Consider first the entry subsidy. The first two columns of table 7 gives the percentage deviation from the baseline for various statistics. The lower cost induces more entry, as expected. It also results in lower dispersion and concentration. In unequal sectors, as more firms enter, they innovate upon the follower, causing these sectors to be less unequal. In neck-in-neck sectors, entrants become the leader as they enter, turning these sectors unequal. However, these entrants have less customer capital, hence does less innovation, compared to if an incumbent with high capital stock innovated out of a neck-in-neck sector. These unequal sectors grow more unequal at a slower rate. The net result is a decrease in dispersion on average. Moreover, the growth rate slightly decreases. The growth rate depends on the average innovation over all firms and potential entrants. The entry subsidy directly increases potential entrant innovation. Follower innovation decrease from higher exit rate, and leader innovation decrease from the higher rate of catch-up. More entrants in neck-in-neck sectors implies more leaders with low customer capital, hence low innovation.

Compared to its effect in an environment without customer capital, the entry subsidy has much larger impact dispersion and concentration when customer capital is present. This stems from the leaders with low customer capital.

	10% subsidy to entry cost		10% subsidy to R&D cost	
	With customer capital	Without customer capital	With customer capital	Without customer
Revenue productivity dispersion	-5.58%	-1.79%	+10.99%	+3.66%
Mean market share	-1.18%	-0.35%	+2.28%	+0.93%
Aggregate Markups	-0.78%	-0.24%	+1.60%	+0.56%
Entry rate	+9.46%	+6.69%	-6.03%	-0.09%
Growth rate	+0.00%	+0.49%	+8.30%	+8.22%
Welfare (CE)	+0.10%	+0.20%	+3.41%	+3.51%

Table 7: Entry subsidy

[7]Steady state welfare cannot be compared, as the productivity level matters.

7 Conclusion

This paper studies the interaction between customer capital and firm innovation decisions. I develop a step-by-step model of innovation incorporated with consumption habits. Consumption habits act as customer capital for firms: if a firm increases their sales in the current period, they will enjoy higher and more inelastic demand in future periods. Through changing future demand, customer capital affects the firm's incentives to innovate. Changes in firm innovation then drives movements in industry concentration and aggregate markups.

I apply the model to quantify the effects of changes in aggregate customer capital arising from aging demographics. By shifting demand composition towards old households who have strong habit effects, aging demographics induces the most productive firms in each industry to innovate more relative to their competitors. This results in rising concentration and markups. Through the lens of the model, induced rise in the share of older households in aggregate demand can account for a quarter of the increase in divergence of Research and Development (R&D) spending across firms, the increase in revenue productivity across firms, and the rise in aggregate markups and industry concentration.

I also use the model to consider how customer capital affect the outcomes of government innovation subsidies. Compared to an environment without customer capital, the effect of these innovation policies on productivity dispersion, concentration, and markups is around 3 times as large. This amplification arises from a feedback effect when customer capital is accounted for.

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A revenue productivity estimation

I estimate revenue productivity following Flynn et al. (2019). The approach uses a proxy estimator to estimate the production function (Ackerberg et al. (2015)), but with an additional restriction on returns to scale, which is necessary for identification. I assume a translog production function

$$y_{it} = \theta_t^v v_{it} + \theta_t^k k_{it} + \theta_t^{vv} v_{it}^2 + \theta_t^{kk} k_{it}^2 + \theta_t^{vk} v_{it} k_{it} + a_{it} + \epsilon_{it},$$

where y_{it} is log revenue, v_{it} is log cost of goods sold, k_{it} is log capital, and a_{it} is log revenue productivity. As in De Loecker et al. (2020), I allow for time-varying production function parameters, and estimate separately for each 2 digit NAICS sector.

k_{it} and v_{it} may be correlated with a_{it}, which gives rise to a simultaneity problem if we proceed to estimate the above function via OLS. The key insight is that a_{it} can be expressed as a function of the firm's observables, obtained from inverting out input demand:

$$a_{it} = \omega_t \left(v_{it}, k_{it}, z_{it} \right),$$

where z_{it} captures other factors that affect demand. Output can then be written as

$$y_{it} = \phi_{it} \left(v_{it}, k_{it}, z_{it} \right) + \epsilon_{it}.$$

For a given guess of $\theta_t = \left\{ \theta_t^v, \theta_t^k, \theta_t^{vv}, \theta_t^{kk}, \theta_t^{vk} \right\}$, one can obtain a guess of revenue productivity as

$$\tilde{a}_{it} \left(\theta_t \right) = \phi_{it} \left(v_{it}, k_{it}, z_{it} \right) - \left(\theta_t^v v_{it} + \theta_t^k k_{it} + \theta_t^{vv} v_{it}^2 + \theta_t^{kk} k_{it}^2 + \theta_t^{vk} v_{it} k_{it} \right).$$

I assume a Markov productivity process $a_{it} = g\left(a_{it-1}, \hat{\psi}_{it-1} \right) + \eta_{it}$, where $\hat{\psi}_{it-1}$ is the predicted probability that the firm continues to be in the sample. This gives one moment condition for θ_t:

$$\mathbb{E} \left[k_{it} \eta_{it} \right] = 0.$$

I impose the additional conditions that the return to scale is 1, which gives 3 more moments:

$$\begin{aligned} \mathbb{E} \left[v_{it} \left(RTS_{it} \left(\theta_t \right) - 1 \right) \right] &= 0 \\ \mathbb{E} \left[k_{it} \left(RTS_{it} \left(\theta_t \right) - 1 \right) \right] &= 0 \\ \mathbb{E} \left[\left(RTS_{it} \left(\theta_t \right) - 1 \right) \right] &= 0, \end{aligned}$$

where $RTS_{it}\left(\theta_t\right) = \theta_t^v + \theta_t^k + 2\theta_t^{vv} v_{it} + 2\theta_t^{kk} k_{it} + \theta_t^{vk} v_{it} k_{it}$.

B Proofs and derivations

Proposition 3. *For the 2 period industry duopoly,*

a) Second period payoff π_i *is given by*

$$\pi_i\left(k_{i2}/k_{-i2}, q_{i2}/q_{-i2}\right) = \frac{\left(\frac{k_{i2}^{\theta/\rho}}{k_{-i2}^{\theta/\rho}}\left(\frac{q_{i2}}{q_{-i2}}\right)^{(\rho-1)/\rho} + \frac{1}{\rho}\right)\frac{k_{i2}^{\theta/\rho}}{k_{-i2}^{\theta/\rho}}\left(\frac{q_{i2}}{q_{-i2}}\right)^{(\rho-1)/\rho}}{\left[1 + \frac{k_{i2}^{\theta/\rho}}{k_{-i2}^{\theta/\rho}}\left(\frac{q_{i2}}{q_{-i2}}\right)^{(\rho-1)/\rho}\right]^2};$$

b) For small $\left(\iota_{i1}, \iota_{-i1}\right)$*, first period R&D decision* ι_{i1} *is approximated by*

$$\iota_{i1} = \frac{1}{\gamma}\left[\pi_2\left(k_{i2}/k_{-i2}, \lambda q_{i1}/q_{-i1}\right) - \pi_2\left(k_{i2}/k_{-i2}, q_{i1}/q_{-i1}\right)\right].$$

Proof. In the last period, given habit stocks, firm i solves

$$\max_{c_{i2}}\left[k_{i2}^{\theta/\rho}\left(\frac{c_{i2}}{c_2}\right)^{-1/\rho} c_2^{-1} - \frac{1}{q_{i2}}\right] c_{i2}$$

FOCs give

$$\frac{\rho-1}{\rho} - \frac{1}{q_{i2}} k_{i2}^{-\theta/\rho}\left(\frac{c_{i2}}{c_2}\right)^{1/\rho} c_2 - \frac{\rho-1}{\rho} k_{i2}^{\theta/\rho}\left(\frac{c_{i2}}{c_2}\right)^{\frac{\rho-1}{\rho}} = 0$$

Define inverse markup $\mu_{i2}^{-1} = \frac{1}{q_{i2}} k_{i2}^{-\theta/\rho}\left(\frac{c_{i2}}{c_2}\right)^{1/\rho}$ and revenue share $s_{i2} = k_{i2}^{\theta/\rho}\left(\frac{c_{i2}}{c_2}\right)^{\frac{\rho-1}{\rho}}$. We then have the system

$$
\begin{aligned}
1-\frac{\rho}{\rho-1}\mu_{i2}^{-1}-s_{i2}&=0\\
1-\frac{\rho}{\rho-1}\mu_{-i2}^{-1}-s_{-i2}&=0\\
s_{i2}+s_{-i2}&=1\\
\frac{\mu_{i2}}{\mu_{-i2}}&=\frac{k_{i2}^{\theta/\rho}}{k_{-i2}^{\theta/\rho}}\frac{q_{i2}}{q_{-i2}}\left(\frac{c_{i2}}{c_{-i2}}\right)^{-1/\rho}
\end{aligned}
$$

This can be solved for to obtain, where $\frac{q_{i2}}{q_{-i2}}=\lambda^m$

$$
\mu_i=\frac{\rho}{\rho-1}\left[1+\frac{k_{i2}^{\theta/\rho}}{k_{-i2}^{\theta/\rho}}\lambda^{m(\rho-1)/\rho}\right]
$$

so that

$$
\pi_i=\left[1+\frac{k_{i2}^{\theta/\rho}}{k_{-i2}^{\theta/\rho}}\lambda^{m(\rho-1)/\rho}\right]^{-2}\left(\frac{k_{i2}^{\theta/\rho}}{k_{-i2}^{\theta/\rho}}\lambda^{m(\rho-1)/\rho}+\frac{1}{\rho}\right)\left(\frac{k_{i2}^{\theta/\rho}}{k_{-i2}^{\theta/\rho}}\lambda^{m(\rho-1)/\rho}\right)
$$

First period innovation approximation is obtained from FOCs and taking ι_{-i1} to 0. □

Proposition 4. $\frac{\partial^2\pi_2(\kappa_i,m_i)}{\partial m_i\partial\kappa_i}>0$ *iff*

$$
\kappa_i^{1/\rho}\lambda^{m_i(\rho-1)/\rho}<\sqrt{4\left(1-\frac{1}{\rho}\right)^2\left(2-\frac{1}{\rho}\right)^{-2}+\frac{1}{\rho}}+2\left(1-\frac{1}{\rho}\right)\left(2-\frac{1}{\rho}\right)^{-1}.
$$

Proof. From the expression of π above, taking partial derivative wrt m yields

$$
\frac{\partial\pi}{\partial m}=\left(\kappa_i^{1/\rho}\lambda^{m(\rho-1)/\rho}\left(\rho-1\right)/\rho\ln\lambda\right)\left[1+\kappa_i^{1/\rho}\lambda^{m(\rho-1)/\rho}\right]^{-3}\left[\kappa_i^{1/\rho}\lambda^{m(\rho-1)/\rho}\left(2-\frac{1}{\rho}\right)+\frac{1}{\rho}\right]
$$

Further taking partial derivative wrt to $\kappa_i^{1/\rho}$ yields an expression with the same sign as

$$
-\kappa_i^{2/\rho}\lambda^{2m(\rho-1)/\rho}\left(2-\frac{1}{\rho}\right)+\kappa_i^{1/\rho}\left(4\lambda^{m(\rho-1)/\rho}\left(1-\frac{1}{\rho}\right)\right)+\frac{1}{\rho}
$$

Let $y = \kappa_i^{1/\rho} \lambda^{m(\rho-1)/\rho}$. The above reduces to

$$- \left(y - 2 \left(1 - \frac{1}{\rho}\right) \left(2 - \frac{1}{\rho}\right)^{-1} \right)^2 + 4 \left(1 - \frac{1}{\rho}\right)^2 \left(2 - \frac{1}{\rho}\right)^{-2} + \frac{1}{\rho}$$

Apply the quadratic formula to solve for y, and setting it to be postie yields the condition. $\square$