Inequality, Openness, and Growth through Creative Destruction

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Abstract

We examine how inequality and openness interact in shaping the long-run growth prospects of developing countries. To this end, we develop a Schumpeterian growth model with heterogeneous households and non-homothetic preferences for quality. We show that inequality affects growth very differently in an open economy as opposed to a closed economy: If the economy is close to the technological frontier, the positive demand effect of inequality on growth found in closed-economy models may be amplified by international competition. In countries with a larger distance to the technology frontier, however, rich households satisfy their demand for high quality via importing, and the effect of inequality on growth is smaller than in a closed economy and may even be negative. We show that this theoretical prediction holds up in the data, both when considering growth in export quality at the industry level and when considering growth in GDP per capita.

Keywords creative destruction · distance to frontier · dual economy · growth · inequality · infant industry protection · non-homothetic preferences · trade openness

JEL Classification D30 · F43 · O15 · O30 · O40

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1 Introduction

In recent years, few topics have been debated more than the rise in income inequality and countries' openness to trade. Many academic and political debates are around winners and losers from international trade in terms of income. With respect to economic growth, there is a well-developed literature on how income inequality affects growth,[1] and a large body of work examining the relation between openness and economic growth.[2] However, much less is known about how income inequality and trade openness interact in shaping a country's long run prosperity. This is the focus of the present paper. This question is of particular importance for developing countries which can exhibit enormous income inequality and have often been under pressure by industrialized countries or international organizations to open their economies for international trade.

To examine how inequality and openness interact in shaping long-run economic growth, we consider a Schumpeterian growth model with heterogeneous households and non-homothetic preferences for quality. So far, the literature has used this type of framework to analyze the effects of inequality on growth in closed economies. The innovation of this paper is that we consider an open economy and show why and how the effects change when allowing for international trade. In particular, we show how the positive effect of inequality on growth found for closed economies can turn negative in an open economy that is not at the technological frontier. The key reason behind this negative relationship is that rich households can satisfy their demand for high quality via importing. Indeed, we document below that developing countries tend to import higher qualities than they produce domestically. We further show that our theoretical predictions regarding the growth effects of inequality in the developing world hold up in the data, both when considering growth in export quality at the industry level and when considering growth in GDP per capita.

Our theoretical model considers two types of households: rich and poor. Households spend their income on a homogeneous good and a continuum of differentiated goods. They consume one physical unit of each differentiated good whose quality they can choose. The households' preferences reflect a complementarity between the quantity of the homogeneous good and the quality of each differentiated good. Therefore, richer households demand more of the homogeneous good and higher qualities of the differentiated goods.

[1] Several channels of how income inequality affects growth have been put-forward in the literature: Inequality might affect growth via differential propensities to save between income groups (Kaldor, 1955), via credit constraints that limit the ability of poor households to invest in the built-up of their human capital (Galor and Zeira, 1993; Galor and Moav, 2004), or via their impact on the political process and hence institutions (Alesina and Rodrik, 1994; Persson and Tabellini, 1994; Gersbach et al., 2019b). Our focus will be on a demand channel, as in e.g. Matsuyama (2002); Foellmi and Zweimüller (2006); Foellmi et al. (2014); Latzer (2018).

[2] See e.g. Grossman and Helpman (1991a) and the literature discussion in section 2.2.

Production of quality of a given differentiated good is constrained by the set of available blueprints for quality versions of that good. Firms can earn a patent on higher quality versions by investing in R&D and increasing the upper bound on quality for a specific differentiated good. The decision problem of an innovating firm is key to characterizing the equilibrium in the economy.[3] Depending on parameter values, all monopolists either pool households or separate rich from poor households. In the latter case, non-homothetic preferences over quality give rise to multi-quality firms, analogous to Latzer (2018).

In such an economy, innovation and growth depend on households' willingness to pay for high quality products and the market size for high qualities. A higher variance of the income distribution, keeping the skewness and average income constant, implies making the rich richer and the poor poorer while keeping their respective shares in the population constant. In turn, the increase in the income of the rich increases their willingness to pay for quality, making it more lucrative for firms to innovate to serve this demand. This leads to the robust and well known comparative statics result that in a separating equilibrium, an increase in the variance of the income distribution has an unambiguously positive effect on growth in closed economies.

The key point of our paper is that this relationship between inequality and growth may be very different when allowing for international trade. To see this, we develop a small open economy (SOE) variant of our model by adding trade subject to an iceberg trade cost with a technologically advanced rest of the world (ROW).[4] In essence, this implies that if domestic firms in the SOE want to sell innovative high qualities to rich households, they need to outbid import competition for high qualities. At a formal level, we show that this introduces a second set of individual rationality constraints into the innovating firms' decision problem. We then identify three scenarios with respect to the effects of inequality and foreign competition on an SOE that is technologically lagging:

First, if inequality is low, the high quality demand by the rich part of the population is only slightly above the domestic technological frontier, and for these quality levels, the

[3] We show that this decision problem boils down to a problem of optimal non-linear monopoly pricing over quality, but with two key differences when compared to the textbook case (e.g. Bolton and Dewatripont (2005)): First, there is an endogenous upper bound on quality. Second, the shape of a consumer's payoff function from one specific differentiated good depends on the full general equilibrium. The costly quality upgrading implies that firms may find it optimal to pool rich and poor households if differences in income and / or the population share of the rich are small. The dependence of the payoff function on the full general equilibrium allows for interesting general equilibrium feedback effects on the innovation decision by firms. These effects will be particularly interesting in our small open economy analysis.

[4] That is, ROW has already developed blueprints for higher quality versions of the differentiated goods when compared to the SOE. Therefore, while most of the existing literature on inequality and R&D deals (implicitly) with a country at the technology frontier, we are explicitly interested in an economy that is not operating at the technology frontier. We will at times use the term 'developing economy' to refer to the SOE, but to focus on the innovation channel, we consider an SOE that is technologically lagging but otherwise perfectly symmetric to the ROW, i.e. we shut down all other frictions that might impact growth in developing countries.

trade costs effectively shield the domestic firms from international competition, leading to the same equilibrium as in the closed economy.

Second, for higher but still moderate inequality, the high quality demand is further above the domestic technological frontier. Innovating domestic firms now have to face up to the international competition, but are still competitive. In this case, outside competition leads to higher domestic innovation and higher growth. The reason for this positive growth effect of foreign competition is that innovating domestic firms find it optimal to match the offer of foreign competitors for rich households by lowering their price. This triggers interesting general equilibrium effects on innovation: The lower price for the high quality versions of *all* differentiated goods allows rich households to economize on their spending for the differentiated goods and increase their consumption of the homogeneous good. In turn, this boosts their demand for quality due to the complementarity between the homogeneous good and the quality of the differentiated goods. This positive *demand effect* lifts innovation incentives above the respective level in the closed economy.

Third, if inequality is large, the quality demanded by high income earners is substantially above the domestic technological frontier, and it is no longer profitable for all domestic firms to compete with the technologically advanced foreign firms to serve the rich. Consequently, rich households start satisfying their demand for high quality by importing some of the differentiated goods, and the SOE exports the homogeneous good and/or low qualities of the differentiated goods in turn, i.e., the SOE imports higher quality than it exports, in line with our motivating facts below. The key observation is that this has a direct negative *business stealing effect* on innovation and growth. This effect gets larger as inequality increases further, and domestic firms in fewer and fewer differentiated good sectors innovate to serve high qualities to the rich. Interestingly, our work thus also shows how a 'dual economy'—with some innovative and some lagging sectors—can arise in developing countries even in an ex-ante perfectly symmetric set-up. The basic intuition is that the domestic population is not rich enough to satisfy all of its demand for quality by importing pricey high qualities from abroad.

Hence, our work shows how inequality, trade openness, and distance to frontier interact in shaping a country's growth prospects, and this has important implications for the dynamic gains from trade and for policy. We show that firms in countries sufficiently close to the frontier are better positioned to profitably outbid foreign competitors, increasing the scope for stimulating growth via trade liberalizations. On the contrary, in an SOE substantially behind the world's technological frontier, it may be beneficial to impose higher trade barriers to prevent that the economy suffers from the negative business stealing effect on growth.

In summary, our theory suggests that the possibility to import high qualities has important implications for the nexus between inequality and innovation-based growth. In developing countries, rich households can satisfy their demand for quality via importing, giving rise to a negative business stealing effect on growth. This effect is particularly prevalent in unequal and open countries, implying that in the developing world inequality has a smaller or even negative effect on growth in an open economy when compared to a closed economy. To test this key prediction of our theory, we perform two sets of growth regressions: First, standard growth regressions using growth in GDP per capita as the dependent variable. Second, industry-level growth regressions using growth in export quality taken from Feenstra and Romalis (2014) as the dependent variable. In these regressions, we then control for an interaction of inequality and openness—defined either as a continuous or as an indicator variable. Across a broad range of specifications, using either a battery of country controls or country fixed effects, we find that for developing countries this interaction term is typically significantly negative in the industry-level regressions, and still negative—albeit not in all cases significant—in our country-level regressions, in line with our theoretical prediction.

The remainder of this paper is organized as follows. Next we provide additional motivation for our analysis and place our paper within the related literature. Section 3 introduces the model and section 4 solves for the equilibrium. In section 5 we consider the closed economy and section 6 looks at a small open economy. Section 7 forms the empirical part of the paper. Finally, section 8 concludes. All proofs and further details are provided in the appendix.

2 Motivating Facts and Relation to the Literature

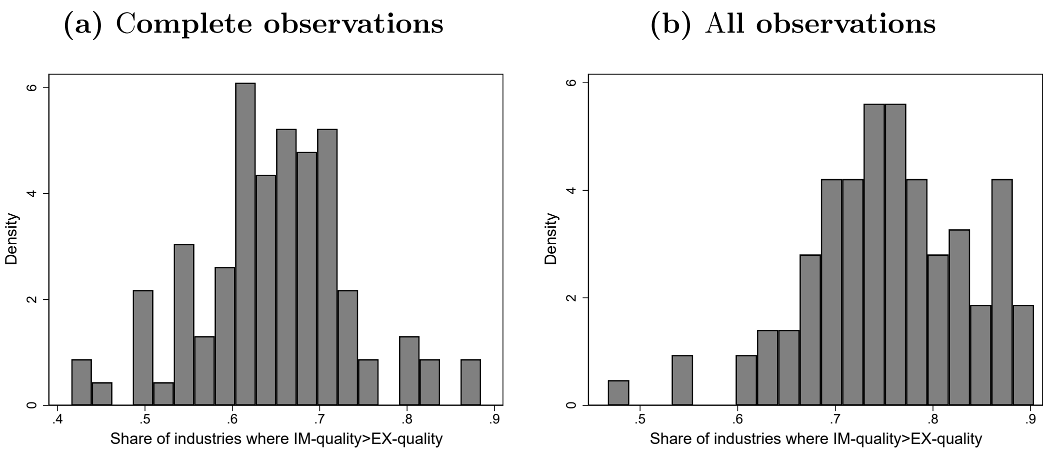
In this section we provide simple motivating facts for our theoretical framework and then relate our paper to the existing literature.

2.1 Motivating facts on imported high qualities

A key premise of our work is that rich households in developing countries can satisfy their demand for high quality via importing. In this section we briefly present anecdotal evidence and stylized facts in support of this premise.

There is plenty of anecdotal evidence that well-off consumers in countries where high-quality products are not produced domestically satisfy their demand by importing high qualities from rich countries. One prominent example are the Intershops in the former Democratic Republic of Germany. These shops accepted only so called Forumschecks as a method of payment which were typically not available to the common people. As

Figure 1: Distribution of relative import quality



Note: Cross-country distribution of the share of industries, where import quality exceeds export quality. Data is from Feenstra and Romalis (2014) and refers to the year 2005. OECD countries, resource-rich countries, and micro states as well as industries with homogeneous goods according to the Rauch (1999) classification have been excluded. The left panel includes observations for which we have data on both import and export quality, while the right panel keeps all observations and sets quality to zero if quality is not observed.

an article in the German news outlet Leipziger Volkszeitung describes it,[5] Intershops offered Western products that were either not at all available in East Germany or at low quality only. The market for luxury goods in China provides another, more recent, example. According to Reuters,[6] Chinese shoppers make up a third of global spendings on luxury goods, which makes them the largest group. Most of these luxury goods are foreign brands, i.e. affluent Chinese citizens increasingly satisfy their demand for high quality goods (in this case, luxury articles) by importing them, and luxury companies, 'are counting on China for the lion's share of their sales growth'.[7] Even for North Korea, we find some evidence that the elite can shop foreign luxury brands in department stores, as CNN writes.[8]

As we show next, the view that elites in developing countries satisfy their demand for high quality via importing is also in line with data on export quality. It is well known that rich countries both export and import higher qualities when compared to poor countries.[9] While this points to non-homotheticicities in demand, we are more interested in knowing whether poor countries import higher qualities than they export, i.e. in comparing the import to the export quality of developing countries, assuming that export quality is a good proxy for qualities made available locally by domestic firms.

To this end, Figure 1 shows the cross-country distribution of the share of industries

[5] Andreas Dunte, Einkaufen wie im Westen, *Leipziger Volkszeitung*, 01. MAR 2014.

[6] Adam Jourdan, China luxury sales rebound as millennials snap up cosmetics, handbags: report, *Reuters*, 17. JAN 2018.

[7] See Robert Williams, Europe's Biggest Luxury Brands Are Nervous About China, *Bloomberg Businessweek*, 18. OCT 2018.

[8] David McKenzie, Where North Korea's elite go for banned luxury goods, *CNN*, 17. JUL 2017.

[9] See Schott (2004), Hallak (2006), Khandelwal (2010), Bastos and Silva (2010), Feenstra and Romalis (2014), Flach (2016), Schetter (2020).

for which import quality exceeds export quality. As our argument concerns developing economies, we exclude OECD countries. As may be seen from Figure 1, non-OECD countries indeed import higher quality than they export in a large majority of industries.[10]

2.2 Literature

Our paper is related to several strands of literature.

Our main focus is on understanding how inequality impacts the growth prospects of a country via the demand for product innovation. These effects are subject to a large and growing literature. Matsuyama (2002) shows in a model of learning by doing that the effect of inequality on growth may be non-monotonic and that conventional measures of inequality such as the Gini-coefficient are not a sufficient statistic for these effects. Foellmi and Zweimüller (2006) consider a model of expanding varieties where new varieties address consumers' needs following their preference hierarchy. Inequality stimulates growth via an associated higher demand for luxury goods. Foellmi et al. (2014) consider product and process innovation, where process innovation prepares 'luxury goods' for mass production, in line with product cycles observed from the data. Latzer (2018) presents a Schumpeterian growth model featuring agents with non-homothetic preferences over quality. She shows how the desire to better discriminate between consumers of different incomes ('surplus appropriation effect') induces incumbents to invest in R&D and can give rise to multi-quality firms in equilibrium.[11] All of these models share in common that they are considering closed economies. And while a change in the income distribution may have non-trivial overall effects on growth, it is the case that a ceteris paribus increase in the income of the rich is beneficial for innovation because it increases their willingness to pay for innovated goods. We show that this channel may be very different, and may, in fact, be reversed in a small open economy.[12]

Our paper is thus also related to the large literature analyzing the growth-effects of international trade (e.g. Grossman and Helpman (1991a), Acemoglu (2003), Galor and Mountford (2008), Nunn and Trefler (2010), Acemoglu et al. (2015), Arkolakis et al. (2018), Gersbach et al. (2019a), Buera and Oberfield (2020)). Openness to trade leads

[10]This is related to Feenstra and Romalis (2014, Figure XIV), who show that export quality is more strongly related to GDP per capita than import quality.

[11]This is in contrast to canonical Schumpeterian models (Aghion and Howitt, 1992) where the replacement effect (Arrow, 1962) outweighs the efficiency effect (Gilbert and Newbery, 1982; Reinganum, 1983).

[12]Hence, at a general level, our work is also related to Matsuyama (2019), who provides a thorough account of Engel's law in a global economy, and its implications for endogenous comparative advantage, structural change, and product cycles, among others. In his case, however, preferences are non-homothetic across sectors, while we consider non-homotheticities within sectors to study Schumpeterian growth. Moreover, he does not consider the effect of inequality within countries on growth, which is our main focus.

to higher competition as foreign firms enter the market. This might reduce R&D incentives for domestic firms and therefore lead to lower growth (Aghion and Howitt, 1992, 1996). At the same time, however, technology spillovers might arise as externalities from international trade (Grossman and Helpman, 1991b; Eaton and Kortum, 1999; Buera and Oberfield, 2020). In line with this, empirical studies rather find a positive relationship between competition and growth (Nickell, 1996; Blundell et al., 1999; Schmitz, 2005), and more recent papers suggest a U-shaped relationship between competition and growth (Aghion et al., 2005, 2009; Hashmi, 2013).[13] The key novelty of our work is that we analyze how the effects of international trade openness interact with inequality in shaping a country's growth prospects.[14,15]

Focusing on developing countries, we show that the growth effects of inequality are generally smaller in open economies than in closed economies because international trade allows rich households to satisfy their demand for high qualities via importing. We then show that this theoretical prediction holds up in growth regressions using either growth in GDP per capita or industry-level growth in export quality taken from Feenstra and Romalis (2014) as the dependent variable. In doing so, we also add to the empirical literature analyzing the linkages from income inequality to economic growth. This literature tends to find a negative effect, but the evidence is far from being conclusive.[16] It has, so far, not considered how the growth effects of inequality depend on a country's openness, which is our main focus here.

[13] Amiti and Khandelwal (2013) show that lower import tariffs (i.e. more competition) lead to quality upgrading for products close to the frontier, but discourages upgrading for products further away from the frontier.

[14] Our work is thus also, but less closely, related to the literature that incorporates non-homothetic preferences into models of international trade (e.g. Flam and Helpman (1987), Stokey (1991), Matsuyama (2000), Fajgelbaum et al. (2011), Fieler (2011), Jaimovich and Merella (2012), or Foellmi et al. (2018a)).

[15] Our work also adds a novel perspective to the discussions on infant industry protection. The theoretical literature on infant industry protection emphasizes the importance of learning-externalities either within or across industries (Krugman, 1987; Lucas Jr., 1988; Young, 1991; Matsuyama, 1992; Krugman and Elizondo, 1996; Puga and Venables, 1999; Hausmann and Rodrik, 2003; Rodrik, 2004; Melitz, 2005; Greenwald and Stiglitz, 2006). Our model also features an externality from innovation on aggregate productivity, and a potentially detrimental effect of trade on growth, which is the basis for infant industry protection. We argue, however, that this effect critically depends on the income distribution in developing countries. See Lee (1996), Davis and Weinstein (2002), Redding and Sturm (2008), Harrison and Rodríguez-Clare (2010), Kline and Moretti (2013), or Juhász (2018) for empirical evidence on the importance of initial conditions for the location of industries because of agglomeration economies and on the effectiveness of infant industry protection.

[16] The early literature indicated a detrimental effect of inequality on growth (cf. the overview in Bénabou (1997)). More recently, Easterly (2007) finds detrimental effects of inequality on growth, highlighting its impact on schooling and institutions, while Ostry et al. (2014) identify negative effects conditional on redistribution. Voitchovsky (2005) finds that inequality at the top is found to be positively related to growth, while inequality further down the income distribution is negatively related to growth, and Halter et al. (2014) show that inequality may be beneficial for short-run growth but detrimental to long-run growth. Barro (2000) finds a detrimental effect of inequality for developing countries, but not so for industrialized countries. Brueckner and Lederman (2018), on the other hand, document that transitional growth is boosted by income inequality in countries with a lower initial income, while the opposite is true for countries with high initial income.

3 Model

To study the growth-effects of inequality, we develop a model with non-homothetic preferences for quality and Schumpeterian growth through quality upgrading. We begin by developing the closed-economy model, which we extend to a small open economy model in section 6.

3.1 Households

The economy is populated by a continuum of infinitely-lived households of measure 1, $h \in [0,1]$. Households derive utility from consumption of a continuum of differentiated goods, $i \in [0,1]$, and a homogeneous good, z. Each differentiated good i represents one distinct consumption need of households that can be satisfied by consumption of one of the available quality versions of the good $q_i(t) \in \mathcal{Q}_i(t)$.[17] In particular, if at time t household $h \in [0,1]$ consumes a bundle $\left\{q_i^h(t)\right\}_{i\in[0,1]}$ of the differentiated goods and $z^h(t)$ units of the homogeneous good, then its instantaneous utility is given by

$$u\left(\left\{q_i^h(t)\right\}_{i\in[0,1]}, z^h(t)\right) = \int_0^1 \left(q_i^h(t)\right)^{1-\beta} di \ \left(z^h(t)\right)^{\beta} \ , \tag{1}$$

and total lifetime utility sums up to

$$U\left(\left\{q_i^h(t)\right\}_{i,t\in[0,1]\times[0,\infty)}, \left\{z^h(t)\right\}_{t\in[0,\infty)}\right) = \sum_{t=0}^{\infty}\left(\frac{1}{1+\rho}\right)^t u\left(\left\{q_i^h(t)\right\}_{i\in[0,1]}, z^h(t)\right) \ .$$

Equation (1) implies that there is a complementarity between the quantity of the homogeneous good and the qualities of the differentiated goods, i.e. richer households have a higher willingness to pay for quality. This will play a central role in our subsequent analysis.[18]

Households maximize their utility subject to their inter-temporal budget constraint

$$a^h(t+1) = (1+r(t))a^h(t) + I^h(t) - \int_0^1 p_i(q_i^h(t);t)\, di \ - p_z(t)z^h \ ,$$

and the no-Ponzi-game condition

$$\lim_{t\to\infty} a^h(t+1)\prod_{t=0}^{\infty}\frac{1}{1+r(t)} = 0 \ .$$

In the above, $p_i(q;t)$ denotes the date t price of quality q of differentiated good i, $p_z(t)$ denotes the date t price of the homogeneous good, $a^h(t)$ are household h's total asset

[17] Hence, there is an infinite degree of substitution between different quality versions of the same good.

[18] A unit requirement for consumption has previously been used by e.g. Jaskold Gabszewicz and Thisse (1980); Shaked and Sutton (1982); Latzer (2018) to model non-homothetic preferences for quality.

holdings at the beginning of period t, $I^h(t)$ denotes its total per-period income net of interest earnings, and $r(t)$ is the per-period interest rate. There are no aggregate investment opportunities in the economy,[19] implying that total net asset holdings are zero, i.e. at any point in time we have[20]

$$\int_0^1 a^h(t)\, dh = 0 \ .$$

Households differ in their endowment with effective labor, ω^h, which they inelastically supply to the labor market. We consider two types of households, a 'high type' with high labour endowment, ω^H, and a 'low type' with low labor endowment, ω^L. Households earn a wage rate w per unit of effective labor, which we choose to be the numéraire, i.e. we have $w(t) = 1$ at all times. To simplify the exposition, we further assume that all households have zero initial endowments $a^h(0) = 0$ at $t = 0$. As we will show in section 4 below, the economy immediately jumps on a balanced growth path. Along this balanced growth path, asset holdings are always 0 for all households and each household just consumes its per-period income I^h. In what follows, we will simplify the notation by ignoring the dependence of all variables on time t unless explicitly stated otherwise.

3.2 Homogeneous good production

The production technology for the homogeneous good is given by

$$z = a_z A L_z \ ,$$

where A denotes the aggregate state of technology, as detailed below, L_z denotes effective labor input, and a_z is a time-invariant productivity parameter. There is perfect competition in the market for the homogeneous good, implying that its equilibrium price is

$$p_z = \frac{1}{a_z A} \ .$$

3.3 Differentiated good production and innovation

One unit of quality q_i of variety i can be produced using the following linear technology

$$q_i = a_q A L_i \ ,$$

where L_i denotes effective labor input and a_q is a time-invariant productivity parameter.

[19] A free-entry condition will guarantee that profits are always equal to zero, see section 3.3.

[20] The main focus of our work is on how income inequality impacts aggregate growth via demand-induced quality upgrading. While we could in principle allow for aggregate savings, e.g. by introducing capital as a second factor of production, this would not affect our main mechanism of interest over and above any potential effect on the income distribution. We therefore simplify the exposition by ignoring this possibility throughout.

Blueprints for quality versions of each differentiated good i are inherited from the previous period up to the threshold quality level $\bar{q}_i(t-1)$. These blueprints are publicly available and there is a competitive fringe of firms that might enter the market.

Blueprints for new, higher-quality versions of each differentiated good can be developed through innovation.[21] Innovation entails two types of cost, both in terms of effective labor: An endogenously chosen fixed cost f_i to set-up a research lab, and research cost

$$h\left(\frac{\bar{q}_i(t)}{\bar{q}_i(t-1)}\right) \tag{2}$$

to push the technological frontier for product i from $\bar{q}_i(t-1)$ to $\bar{q}_i(t)$, where $h(\cdot)$ is C^2 and satisfies: $h(1) = 0$, $h'(1) = 0$, and $h''(\cdot) > 0$. Successful innovation results in a one-period patent for all qualities $q_i \in (\bar{q}_i(t-1), \bar{q}_i(t)]$. There is free entry into innovation and firms engage in a patent race. Our main interest is in understanding how inequality and openness to trade impact endogenous quality upgrading. We will therefore simplify matters by assuming that the firm with highest set-up investments f_i always wins the patent race. In the only subgame-perfect equilibrium there will then be just one firm per differentiated good that engages in innovation, and the total set-up costs of this firm, f_i, are equal to its subsequent monopoly profits.[22]

With the expiration of patents, production knowledge accumulated in the research and development process and in the production of new, high-quality varieties spills over to the entire economy. Such spillovers give rise to the following aggregate technology $A(t+1)$

$$A(t+1) = \int_0^1 \bar{q}_i(t)\, di \ .$$

In what follows, we will consider the case of a common inherited quality level $\bar{q}_i(t-1) = \bar{q}(t-1)\ \forall\, i \in [0,1]$. In a symmetric equilibrium, this then implies $A(t) = \bar{q}(t-1)$ and the following law of motion for aggregate technology[23]

$$A(t+1) = \frac{\bar{q}(t)}{\bar{q}(t-1)} A(t) \ .$$

[21] For concreteness, we refer to the process of quality upgrading as innovation. But considering our focus on countries not at the frontier, we can alternatively interpret quality upgrading as imitation of advanced technologies.

[22] Allowing for positive profits by innovating firms would not directly effect the optimal choice of $\bar{q}_i(t)$ and, hence, aggregate growth. Profits would, however, have a general equilibrium feedback effect on innovation via their implications for the income distribution. While it is possible to incorporate such feedback loops, it would complicate the analysis without adding anything of substance to our main insights. We therefore consider the analytically more tractable case with zero profits in equilibrium. A free entry condition and, hence, zero profits in equilibrium is a common assumption in endogenous growth models. In these models, higher investment costs in R&D typically result in higher innovation probabilities and, hence, growth. We will get back to this point in section 6.4, and for now focus on our main growth channel of interest: the endogenous quality margin.

[23] In section 4 we will show that in the closed economy with a common inherited quality level $\bar{q}_i(t-1)$, the unique equilibrium is symmetric.

3.4 Firms' decision problem

An innovating firm needs to decide whether and how much to invest in R&D in order to expand the set of blueprints for qualities from its current level $\bar{q}_i(t-1)$ to some new level $\bar{q}_i(t) > \bar{q}_i(t-1)$. This decision is driven by the profit potential associated with these new blueprints. The competitive fringe for all pre-existing qualities $q_i \leq \bar{q}_i(t-1)$ pushes down their price to marginal cost, i.e.

$$p_i(q) = \frac{1}{a_q A} q \;, \quad \forall\, q \leq \bar{q}_i(t-1) \;,$$

implying zero profits on these qualities. By contrast, an innovating firm can freely set the price $p_i(q)$ for all qualities $q \in (\bar{q}_i(t-1), \bar{q}_i(t)]$. The innovating firm then chooses $\bar{q}_i(t)$ and $\{p_i(q)\}_{\bar{q}_i(t-1)}^{\bar{q}_i(t)}$ to maximize its total profits

$$\Pi_i = \int_{\bar{q}_i(t-1)}^{\bar{q}_i(t)} \left[p_i(q) - \frac{1}{a_q A} q \right] D_i(q; p_i)\, dq - h\left(\frac{\bar{q}_i(t)}{\bar{q}_i(t-1)} \right) \;, \tag{3}$$

taking as given the demand for quality q of good i, $D_i(q; p_i)$, where we used p_i to denote the set of prices for each quality of differentiated good i, $p_i := \{p_i(q)\}_{q \in \mathcal{Q}_i}$.

Let superscripts $h = \{H, L\}$ refer to high and low types, respectively, and let λ denote the share of high types in the economy. The decision problem of the innovating firm for good i then boils down to the following:

Lemma 1
The decision problem of innovating firm i is equivalent to:

$$\max_{q_i^H, p_i^H, q_i^L, p_i^L, \bar{q}_i(t)} \quad \lambda \left(p_i^H - \frac{1}{a_q A} q_i^H \right) + (1-\lambda) \left(p_i^L - \frac{1}{a_q A} q_i^L \right) - h\left(\frac{\bar{q}_i(t)}{\bar{q}_i(t-1)} \right)$$

$$\text{s.t.} \quad \theta^h v(q_i^h) - p_i^h \geq \operatorname{argmax}_{q \in [0, \bar{q}_i(t-1)]} \left\{ \theta^h v(q) - \frac{1}{a_q A} q \right\} \;, \quad h \in \{L, H\} \tag{IR}$$

$$\theta^H v(q_i^H) - p_i^H \geq \theta^H v(q_i^L) - p_i^L \tag{IC$^{\mathrm{H}}$}$$

$$\theta^L v(q_i^L) - p_i^L \geq \theta^L v(q_i^H) - p_i^H \tag{IC$^{\mathrm{L}}$}$$

$$q_i^h \leq \bar{q}_i(t), \quad h \in \{L, H\} \,.$$

where $v(q) := q^{1-\beta}$ and where the firm considers type $\theta^h := \frac{p_z z^h}{\beta Q^h}$, $Q^h := \int_0^1 {q_i^h}^{1-\beta}\, di$, of household $h \in \{L, H\}$ as exogenously given. The value θ^h is private knowledge to the household.

The proof of Lemma 1 is given in appendix C.1. The optimization problem reflects the standard assumption in monopolistic competition models according to which the individual firm has no impact on aggregate outcomes.

The firm's decision problem is one of optimal non-linear monopoly pricing over qualities, but with an endogenous choice of the upper bound on qualities and where the distribution of household types is given by the endogenous distribution of θ.[24] The set of constraints in the firm's optimization problem is a reflection of the revelation principle, according to which the optimal set of contracts is one contract for each type of households such that each household has an incentive to truthfully reveal its type. Accordingly, the first set of constraints requires that contracts are *individually rational* (IR), that is, each household must prefer its contract over its best outside option, which is in our case to consume the best option from the set of qualities that are available at marginal cost. The second set of constraints requires that contracts are *incentive compatible* (IC), i.e. every household must prefer their contract over the contract designed for the other type in the economy. Finally, the last constraint dictates that all qualities must be feasible, i.e. they cannot exceed the current technological frontier for the respective good.

As we show in lemma 2, θ as defined in lemma 1 is an increasing function of household income and, hence, of their endowment with effective labor. In turn, this implies that households with higher income demand products of higher quality levels.

Lemma 2
θ^h is strictly increasing in I^h.

The proof of lemma 2 is given in appendix C.2.

4 Equilibrium

We are now ready to analyze the equilibrium in the closed economy. As we discuss in section 3, every household splits its budget between a certain amount of the standard good z and a certain quality of each of the differentiated goods. Due to the complementarity between the homogeneous good and the differentiated goods, the richer households have a higher willingness to pay for quality. If all qualities were offered at marginal costs, each household possesses an optimal quality level at which it wishes to consume the differentiated good, and these optimal quality levels are a direct mapping from the households' incomes. On the contrary, given a certain technological level $\bar{q}(t-1)$, we can define the income level $\hat{I} := 1/[a_q(1-\beta)]$ for which a household would choose quality $\bar{q}(t-1)$ as its optimal quality priced at marginal costs. This implies that only households with income higher than $\hat{I}$ may be interested in innovations in quality while households with income lower than this threshold will always consume their ideal and already available quality

[24]Hence, the decision problem differs in two important ways from the textbook case of non-linear monopoly pricing over qualities (e.g. Bolton and Dewatripont (2005)). As we will see, this has important implications. On the one hand, with an endogenous upper bound on quality it may or may not be optimal to pool households at the top to economize on costs of innovation. On the other hand, the endogeneity of θ introduces feedback effects from the overall economy on the firms' behavior. These feedback effects have to be taken into account throughout. They will be of particular interest in the small open economy variant below.

priced at marginal costs. Using this, we can characterize the unique equilibrium in the economy as follows:

Proposition 1

There is a unique equilibrium satisfying for $h = \{H, L\}$*:* $q_i^{h^e} = q^{h^e}$ *and* $p_i^{h^e} = p^{h^e}$ $\forall\, i \in [0,1]$. *This equilibrium can be characterized according to the following cases:*

(i) If both types' income levels are below $\hat{I}$, $\boldsymbol{I^L \leq I^H \leq \hat{I}}$,
then all quality levels demanded already exist, $q^{L^e} \leq q^{H^e} \leq \bar{q}(t-1)$ *and are offered at* p^{L^e} *and* p^{H^e} *reflecting marginal costs. There are no innovation incentives.*

(ii) If only the high types' income level exceeds $\hat{I}$, $\boldsymbol{I^H > \hat{I} \geq I^L}$,
then there is a separating equilibrium where the quality level demanded by the low types already exists, $q^{L^e} \leq \bar{q}(t-1)$ *and is offered at* p^{L^e} *reflecting marginal costs. The quality level demanded by the rich exceeds the highest pre-existing quality level and the firms innovate to provide* $q^{H^e} > \bar{q}(t-1)$*, which is offered with a mark-up at* p^{H^e}.

(iii) If both types' income levels exceed $\hat{I}$, $\boldsymbol{I^H \geq I^L > \hat{I}}$,
then depending on parameter values, there can be three different equilibria:

(A) There is a separating equilibrium, where the low types purchase the already available quality $q^{L^e} = \bar{q}(t-1)$ *offered at* p^{L^e} *reflecting marginal costs and the firms innovate to provide* $q^{H^e} > \bar{q}(t-1)$ *for the high types, which is offered with a mark-up at* p^{H^e}.

(B) There is a separating equilibrium, where the firms offer different innovations in quality to the different types $\bar{q}(t-1) < q^{L^e} < q^{H^e}$ *with mark-ups of different sizes at* $p^{L^e} < p^{H^e}$.

(C) There is a pooling equilibrium, where the firms offer the same innovation in quality to both types $\bar{q}(t-1) < q^{L^e} = q^{H^e}$ *with an appropriate mark-up at* $p^{L^e} = p^{H^e}$.

The precise, technical version of proposition 1 and the proof are provided in appendix C.3. The intuition of the equilibrium is as follows. In the first case, as described in proposition 1(i), the technological level in the economy is high enough so that the optimal quality levels of households of both types are available and be consumed at marginal costs. As a consequence, there are no innovation incentives and economic growth is zero.

In case (ii), only the low income households can find their optimal quality among the already available ones while the high income households wish to consume at higher qualities than currently available. This implies that firms can make profits by offering higher quality and, hence, have an incentive to push up the technological frontier. This leads to positive growth driven by the demand of the rich households.

In the situation depicted in (iii), the existing technological level is so low that both the high and the low income households will not be able to consume their most desired quality level at marginal cost. Then the firm has an incentive to innovate to satisfy the quality demands of the households. In maximizing its profits the firm has to decide how much to invest in quality innovation and whether to offer two different quality levels for the different household types. In case (A), the firm innovates to cater to the quality demand of the rich households, while the poor households consume the best already existing quality at marginal costs. The reason is that if the firm offered another quality level above $\bar{q}(t-1)$ for the low income households, it would be favorable for the rich households to consume at this lower quality level as well or the firm had to reduce the price for the high quality to keep the rich households consuming the higher quality. The corresponding gains in profits from the poorer households do not compensate for the losses in profits from the rich customer base. In (B) the share of the poor is sufficiently large that it is no longer optimal to ignore them while income differences between the poor and the rich are sufficiently high such that it is beneficial to push out the technological level further to offer high qualities for the rich and lower qualities, but still higher than $\bar{q}(t-1)$, for the poor. This is a separating equilibrium where both types of households are served by innovating firms, i.e. we observe multi-quality firms in equilibrium.[25] Finally, the share of the rich and income differences are not large enough in case (C), such that it is optimal for firms to pool households.

Proposition 1 and its technical version in appendix C.3 characterize the equilibrium qualities and prices of the differentiated goods consumed by poor and rich households, respectively. Equipped with these, we can use the household budget constraints to derive the respective consumption levels of the homogeneous good. This completes the characterization of the unique equilibrium in the economy. Note that all expressions in proposition 1—see the detailed version in appendix C.3—involve only, $\frac{q^{L^e}}{\bar{q}(t-1)}$, $\frac{q^{H^e}}{\bar{q}(t-1)}$, p^{L^e}, p^{H^e}, and time-invariant parameters, i.e. the aggregate growth rate $g^e = \frac{q^{H^e}}{\bar{q}(t-1)}$ is constant over time, which constitutes the following corollary.

Corollary 1

There is a unique balanced growth path (BGP) which is reached instantaneously. Along the BGP, the growth rate is $g^e = \frac{q^{H^e}}{\bar{q}(t-1)}$.

We will now analyze how a change in the income distribution impacts the equilibrium outcomes in proposition 1 and, in particular, q^{H^e} which governs growth in our case. To simplify notation, we will throughout dispose of the superscript ^{e} to indicate equilibrium outcomes.

[25] See Latzer (2018) for a detailed account of the endogenous emergence of multi-quality firms in such an environment.

5 Inequality and Growth: The Closed Economy

Without loss of generality, we normalize endowments with effective labor such that

$$E[\omega] = \lambda\omega^H + (1-\lambda)\omega^L = 1 \equiv \bar{w} \ .$$

We further choose

$$\omega^H = 1 + \sigma\sqrt{(1-\lambda)/\lambda}, \qquad \omega^L = 1 - \sigma\sqrt{\lambda/(1-\lambda)} \ ,$$

where $\sigma \geq 0$, as this specification allows to separate changes in the variance of the income distribution from changes in its skewness[26]

$$VAR(\omega) = \sigma^2, \qquad SK(\omega) = (1-2\lambda)/(\sqrt{\lambda(1-\lambda)}) \ .$$

To analyze the impact of inequality on growth in our economy, we then focus on changes in the variance (i.e., in σ). This corresponds to a Lorenz-dominated shift of the income distribution and allows isolating our main mechanism of interest—an inequality-induced higher willingness to pay for innovation—and its implications in a closed vs open economy.[27] The following proposition characterizes the growth effects of such a change in inequality in the closed economy.

Proposition 2
Changes in the variance of the income distribution have the following effects on economic growth:

(i) If $\hat{I} \geq \bar{w}$, economic growth monotonously increases with the variance of the income distribution.

(ii) If $\hat{I} < \bar{w}$, there is a U-shaped relationship between the variance of the income distribution and economic growth. The lowest growth rate is at the level of σ where the equilibrium type changes from a pooling to a separating equilibrium.

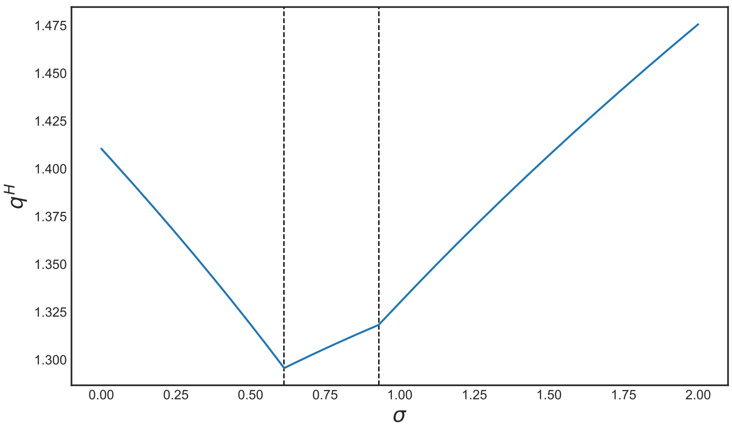
The proof of proposition 2 is given in appendix C.4.[28]

[26] Our specification of endowments with effective labor relates to Foellmi et al. (2014) and Latzer (2018) as follows. As in Foellmi et al. (2014) and Latzer (2018), an increase in σ increases the income gap and leaves the share of poor households unchanged. Therefore, an increase in σ always increases inequality and a policy reducing σ leads to a Lorenz-dominating shift. On the other hand, an increase in income concentration (i.e. a decrease in λ) in our setting also increases the income gap. Hence, a change in λ leads to a Lorenz-crossing shift, as we cannot disentangle changes in income concentration and the income gap when varying λ. Unlike the specification in Foellmi et al. (2014) and Latzer (2018), λ is therefore not monotonously related to measures of inequality.

[27] We also have results for the effects of skewness on economic growth in the closed economy, which we are glad to share upon request.

[28] The statements for a separating equilibrium where both types are still served are partially based on numerical solutions for a broad range of parameter specifications, see appendix C.4.

Figure 2: q^H for different values of σ $[\hat{I} < \bar{\omega}]$



Note: The figure shows the equilibrium values of q^H for different values of σ and where $\hat{I} < \bar{\omega}$. The dashed lines indicate changes in the type of equilibrium, first from a pooling to a separating equilibrium and then to a separating equilibrium where only rich households are served by innovating firms. The remaining parameter values are $a_q = 12$, $\beta = 0.5$, $\lambda = 0.2$, and $\bar{q}(t-1) = 1$. Furthermore, $h'(x) = x - 1$.

The central element for innovation is its value to the firm. This value depends on the market size and the willingness to pay for higher quality. The former is reflected by what share of the households have incomes above $\hat{I}$, while the latter depends on how much larger these incomes are than $\hat{I}$. Proposition 2 distinguishes two cases. In case (i), the average wage is below the income level $\hat{I}$ necessary to have a willingness to pay a premium for a quality above the currently available $\bar{q}(t-1)$. As a consequence, with an equal distribution of wages, the households would consume their existing optimal quality level priced at marginal costs. This implies that there are no innovation incentives and consequently no growth with an equal distribution of incomes. A higher variance in incomes means larger incomes for a share λ of the population at the expense of the remaining $1-\lambda$ households. Innovation and economic growth become positive when the rich share of society realizes incomes larger than $\hat{I}$. Innovation incentives increase further as we keep on increasing σ, as the willingness to pay for quality of the rich increases while the market size remains constant at λ. For this reason higher variance σ implies higher economic growth as stated in the proposition.

The results in the second part of proposition 2 are based on the same economic intuition. However, as $\hat{I} < \bar{w}$, at an equal distribution of incomes the households would like to consume higher quality levels than $\bar{q}(t-1)$, implying positive gains from innovation. Hence, economic growth would be positive in such case. As we increase σ starting from an equal income distribution, we now have to consider the different types of equilibria described in proposition 1. Initially, as we increase the variance, a pooling equilibrium will persist, but with the low income households showing a lower willingness to pay for quality and thereby leading to lower equilibrium quality and prices. As we increase the variance further, the willingness to pay for quality of high income households is eventually large enough to justify additional investments in quality upgrading on the side of innovating firms despite the fact that only a fraction $\lambda < 1$ of households are rich. This means that there will be a separating equilibrium. In the separating equilibrium, innovation incentives are centrally driven by the willingness-to-pay of the rich. This is where innovation incentives and growth are increasing in σ. Taken together, there is a U-shaped relationship between σ and growth, where the minimum is reached at the point where the economy switches from a pooling to a separating equilibrium, as illustrated in figure 2.

Next, we consider a small open economy and show that in developing countries international trade can have profound consequences for the growth effects of inequality.

6 Inequality and Growth: Small Open Economy

We next consider a small open economy (SOE) variant of our model to examine how the opportunity to trade impacts the identified link between inequality and growth. In this variant, households can satisfy their demand for any of the goods by importing it from a rest of the world (ROW) that is technologically more advanced, but perfectly symmetric to the SOE otherwise, for simplicity. Specifically, we assume that $a_z^{SOE} = a_z^{ROW} = a_z$, $a_q^{SOE} = a_q^{ROW} = a_q$, and that $\bar{q}^{SOE}(t-1) < \bar{q}^{ROW}(t-1)$. Trade between the SOE and the ROW is subject to an iceberg trade cost $\tau > 1$ that is the same across all sectors, and domestically or foreign produced versions of any given quality of a good are perfect substitutes to one another.

We begin with some preliminary considerations on international trade and the firms' decision problem, before analyzing the inequality-growth nexus in the open economy.

6.1 Preliminary considerations

To analyze the equilibrium in the SOE, note first that the symmetry of the set-up immediately implies that there cannot be two-way trade of any given quality of a good. Hence, balanced trade is possible only if the SOE imports some high qualities $q > \bar{q}^{SOE}(t)$ from abroad and exports the homogeneous good z and / or, qualities $q \leq \bar{q}^{SOE}(t)$ of the differentiated goods, in line with our stylized facts from section 2.1. In turn, this requires that the SOE can price the homogeneous good competitively in the world market, i.e.[29]

$$p_z^{ROW} = \tau \frac{w^{SOE}}{a_z A^{SOE}} = \frac{w^{ROW}}{a_z A^{ROW}} \ . \tag{4}$$

[29]Note that equation (4) implies that firms in the SOE have strictly lower marginal production costs for the homogeneous good and for all qualities $q \leq \bar{q}^{SOE}(t)$ than the marginal cost of firms from the ROW of serving customers in the SOE. It follows that, indeed, the only equilibrium with positive and balanced trade is one where the SOE imports high qualities and exports low qualities and / or the homogeneous good.

Foreign firms are willing to serve consumers in the SOE at their marginal costs scaled by the iceberg trade costs τ.[30] The marginal costs for firms from the ROW of serving quality q to consumers in the SOE are: $\tau \frac{q w^{ROW}}{a_q A^{ROW}}$. Using $w^{SOE} = 1$ again and noting that

$$w^{ROW} = \frac{\tau A^{ROW}}{A^{SOE}} w^{SOE}$$

by equation (4), these marginal costs—and, hence, the price at which imported qualities are offered to consumers in the SOE—can be restated as

$$p^f(q) = \tau^2 \frac{1}{a_q A^{SOE}} q \ ,$$

where here and in the following, we use a superscript ^{f} to denote an offer from foreign firms to consumers in the SOE.

In this set-up, firms in the SOE cannot make profits from selling differentiated goods to the ROW.[31] Yet, the availability of imported qualities impacts innovation incentives in the SOE, because imported qualities introduce a second set of individual rationality constraints for households: In the SOE, a contract offered by a domestic monopolist must not only be preferable to a household's best choice among the domestic competitive fringe, but also to its best import option. This gives rise to the following augmented decision problem for innovating firms in the SOE:[32]

$$\begin{aligned}
\max_{q_i^H, p_i^H, q_i^L, p_i^L, \bar{q}_i(t)} \quad & \lambda \left(p_i^H - \frac{1}{a_q A} q_i^H \right) + (1-\lambda) \left(p_i^L - \frac{1}{a_q A} q_i^L \right) - h \left(\frac{\bar{q}_i(t)}{\bar{q}_i(t-1)} \right) \\
\text{s.t.} \quad & \theta^h v(q_i^h) - p_i^h \geq \operatorname{argmax}_{q \in [0, \bar{q}_i^{SOE}(t-1)]} \left\{ \theta^h v(q) - \frac{1}{a_q A} q \right\} \ , \quad h \in \{L, H\} \\
& \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \text{(IR)} \\
& \theta^h v(q_i^h) - p_i^h \geq \operatorname{argmax}_{q > 0} \left\{ \theta^h v(q) - \tau^2 \frac{1}{a_q A} q \right\} \ , \quad h \in \{L, H\} \qquad \text{(IRf)} \\
& \theta^H v(q_i^H) - p_i^H \geq \theta^H v(q_i^L) - p_i^L \qquad \text{(IC}^{\text{H}}\text{)} \\
& \theta^L v(q_i^L) - p_i^L \geq \theta^L v(q_i^H) - p_i^H \qquad \text{(IC}^{\text{L}}\text{)} \\
& q_i^h \leq \bar{q}_i(t), \quad h \in \{L, H\} \, .
\end{aligned}$$

It is useful to simplify the above decision problem by solving for the value of the best import option of a household of type θ^h. In particular, household h's best import option

[30] If $q \leq \bar{q}^{ROW}(t-1)$, this is the case because of the competitive fringe in the ROW. If $q > \bar{q}^{ROW}(t-1)$, it follows because the SOE is small and, therefore, firms from the ROW do not have to redeem R&D costs from profits in the SOE. If trade costs are sufficiently small, pricing in the SOE of monopolistic firms from the ROW may be constrained by a threat of re-importing to the ROW (see e.g. Foellmi et al. (2018b)). We leave such considerations out of account here. Note that we can always rule out a threat of re-importing if the SOE is sufficiently far from the technological frontier such that the imported qualities satisfy $q \leq \bar{q}^{ROW}(t-1)$.

[31] Firm i may sell some qualities $q \in (\bar{q}_i^{SOE}(t-1), \bar{q}_i^{SOE}(t)]$ to the ROW, but if it does, it sells them at its marginal cost of delivering these qualities to the ROW.

[32] Analogously to the best option from the domestic competitive fringe, we assume that in case of indifference the household consumes the domestic quality and not an imported quality.

is to choose quality $q^{h,f}$ such that $\theta^h v'(q^{h,f}) = \tau^2/(a_q A)$. It follows immediately that its optimal import quality is

$$q^{h,f} = \left[\frac{(1-\beta)\theta^h a_q A}{\tau^2}\right]^{\frac{1}{\beta}} , \tag{5}$$

which implies for the value of the optimal import quality

$$\theta^h v(q^{h,f}) - \frac{q^{h,f}\tau^2}{a_q A} = \left[\theta^h\right]^{\frac{1}{\beta}} \left[\bar{q}(t-1)\right]^{\frac{1-\beta}{\beta}} \underbrace{\left[\frac{a_q(1-\beta)}{\tau^2}\right]^{\frac{1-\beta}{\beta}} \beta}_{:=\chi(\tau)} . \tag{6}$$

Observe from equation (6), that the value of the best import option is convex in θ^h, reflecting the fact that higher types not only value quality more, but that they also consume higher quality. This convexity implies that for sufficiently high levels of inequality, (IRf) is binding for the high types.

In what follows, we analyze how innovation and growth in the SOE depend on inequality. To that end, we make the following restrictions: First, in the SOE, the optimal solution to the firms' decision problem and, hence, growth still depends crucially on whether or not $I^h > \hat{I} := \frac{1}{a_q(1-\beta)}$ for $h \in \{L, H\}$, as households with income $I^h \leq \hat{I}$ always find it optimal to consume a quality from the domestic competitive fringe at marginal costs. In what follows, we consider the most comprehensive case where $\hat{I} < \bar{w}$ and then study an increase in σ. In this case, $I^h > \hat{I}$ for $h \in \{L, H\}$ as long as σ is small, and $I^L \leq \hat{I}$ for σ large enough, i.e. this case involves the most intricate trade-offs. Moreover, for large values of σ it is analogous to the case of $\hat{I} > \bar{w}$.

Second, we consider a case where initially, at $\sigma = 0$, (IRf) is strictly non-binding as this will imply that our analysis covers the different scenarios with regards to the effect of inequality on growth in the SOE as discussed in the next section. To ensure this, we henceforth assume that trade costs exceed a minimum threshold $\tau \geq \underline{\tau}$ based on structural parameters of the model as specified in appendix B.1. Specifically, as we show in the appendix, this restriction implies that—irrespective of σ—only the rich part of society may find it beneficial to import foreign high quality products, but not the poor, in line with our motivating fact.

Finally, of course $q^{h,f}$ is feasible only if $q^{h,f} \leq \bar{q}^{ROW}(t)$. This is true as long as the SOE is sufficiently far from the frontier, and we will consider this case first, as it introduces the fiercest foreign competition for innovating domestic firms and is arguably most relevant for developing countries far from the frontier. The case where $q^{h,f} > \bar{q}^{ROW}(t)$ is qualitatively similar, but it provides domestic firms with greater potential to block foreign entry. We discuss this latter case in section 6.3 and in appendix B.3.

6.2 Effects of inequality on growth in the small open economy

We are now ready to characterize the growth effects of inequality in the small open economy. We analyze equilibrium innovation and, hence, growth for sequentially increasing variances of the income distribution, σ. We provide all the technical details of the following explanations in Appendix B.2.

Low levels of inequality

Starting from $\sigma = 0$, constraint (IRf) is non-binding for both household types by assumption. As long as this is the case, an increase in σ trivially has the same effect on growth as in the closed economy: Growth initially declines while still in a pooling equilibrium and eventually increases when σ and, hence, income differences are large enough such that innovating firms find it optimal to separate low types from high types.

Intermediate levels of inequality

As we continue to increase σ, θ^H increases further and eventually is high enough such that high types are indifferent between consuming q^H and their best import option as defined by (5). At this point, if we continue to increase σ, constraint (IRf) will be strictly binding for the high types.[33]

How will innovating firms—and, hence, the economy—respond if their optimal contract for the rich is no longer feasible due to import competition? We address this question for the case where—in the closed economy—innovating firms still find it profitable to also serve the poor. The case where they stopped serving the poor is analogous and follows directly.[34] We know from appendix C.3, that in the closed economy in a separating equilibrium, contracts (q^H, p^H) and (q^L, p^L) satisfy the following optimality conditions

$$\theta^L \left(v(q_i^L) - v(\bar{q}(t-1))\right) + \frac{1}{a_q} = p_i^L \tag{7}$$

$$\theta^H \left(v(q_i^H) - v(q_i^L)\right) + p_i^L = p_i^H \tag{8}$$

$$\theta^L v'(q_i^L) - \lambda \theta^H v'(q_i^L) - (1-\lambda)\frac{1}{a_q A} \leq 0 \tag{9}$$

$$\lambda \theta^H v'(q_i^H) - \lambda \frac{1}{a_q A} - h'\left(\frac{q_i^H}{\bar{q}(t-1)}\right)\frac{1}{\bar{q}(t-1)} = 0\ , \tag{10}$$

where condition (9) holds with equality whenever $q_i^L > \bar{q}(t-1)$. Intuitively, equations (7) and (8) dictate that (IR) is binding for the low types while (IC) is binding for the high types. Condition (9) weighs the gains from marginally increasing the quality for the low types—and, hence, their willingness-to-pay—against the marginal cost of producing that quality and of marginally tightening (IC) for the high types. (10) weighs the gains

[33] Of course, for τ and λ high enough, (IRf$^{\mathrm{H}}$) is never binding while $I^L \geq 0$. We focus on the economically interesting case where (IRf$^{\mathrm{H}}$) is eventually binding while $I^L \geq 0$ and trade may occur. Note that for any $\tau \geq \underline{\tau}$ we can find a λ small enough such that this is indeed the case.

[34] See also footnote 57.

from marginally increasing the quality for the high types against the marginal cost of production and of innovation, reflecting the fact that q_i^H is always at the frontier.

Now, if the solution to conditions (7) to (10) is no longer feasible because it violates ($\mathrm{IRf^H}$), domestic firms may, in principle, find it optimal to stop serving the rich. In fact, this will eventually be the case for σ high enough, as we will see below. Initially, however,—when ($\mathrm{IRf^H}$) is marginally binding—this is not the case, because in the closed economy firms would make strictly positive profits from serving the rich. Instead, innovating firms marginally improve the value of the contract for the rich such that they are again indifferent between consuming q^H or their best import option. Firms achieve this by lowering the price p^H but, ceteris paribus, keeping the quality q^H unchanged.[35]

While these responses do not impact q^H directly, they have general equilibrium effects on growth: The lower prices p^H for all differentiated goods allow the rich to economize on their spending on the differentiated goods. As a consequence, they consume more of the homogeneous good and θ^H increases, which in turn increases their demand for high quality. This induces firms to increase q^H, despite the lower mark-ups which lead to lower profits net of the fixed innovation cost f_i.[36]

High levels of inequality

Eventually, θ^H is so high that foreign competition is sufficiently strong so that it is no longer profitable for all domestic firms to serve the rich. The rich then start importing some of the differentiated goods, and the SOE imports higher quality than domestically available, in line with our stylized facts. Still, the SOE continues to serve rich households in a subset of the differentiated goods and, in fact, initially in the majority of these goods. This is because when rich households start satisfying their demand for quality via importing, they import higher quality than what domestic firms would offer and, hence, at a higher price. In turn, this has general equilibrium feedback effects on their types, θ^H, that are similar in spirit but of opposite sign as the ones previously discussed for intermediate levels of inequality. Hence, if rich households immediately switched to importing all differentiated goods, it would result in a discrete drop of their willingness to pay for quality, and importing the high qualities from abroad was no longer optimal.

In other words, the equilibrium is no longer symmetric, with some differentiated goods being provided by innovating domestic firms to rich households, while others are imported

[35] This follows from condition (10), which defines q^H as a function of θ^H and equates the total marginal utility from increasing q^H, $\lambda\theta^H v'(q^H)$, to the total marginal cost, $\lambda\frac{1}{a_q A} + h'\left(\frac{q_i^H}{\bar{q}(t-1)}\right)\frac{1}{\bar{q}(t-1)}$. Hence, ceteris paribus a change in q^H cannot be optimal: It would increase (decrease) the willingness-to-pay of the rich by less (more) then it would increase (decrease) the marginal cost of delivering quality to the rich.

[36] In our model, the lower mark-ups are absorbed by the fixed costs f_i as discussed in section 3.3. More generally, lower mark-ups and profits net of fixed costs may well feed back into innovation incentives for firms. See section 6.4 for a discussion.

by the rich—we will get back to this point at the end of this section. The share of differentiated goods that rich households import is small initially and gets larger as we keep on increasing σ. If rich households import a differentiated good, domestic firms may either stop innovating altogether in that good or keep innovating to serve the poor, depending on parameter values. In either case, $\bar{q}_i(t)$ is lower when compared to the closed economy in these goods and, hence, so is $A(t+1)$ and aggregate growth. This effect is the larger the higher inequality and, hence, the larger the share of differentiated goods that rich households import from abroad. We summarize these insights in the following proposition:

Proposition 3
In the small open economy:

(i) For small values of the variance in incomes σ, the only equilibrium is a no-trade equilibrium, that is, equilibrium outcomes are the same as in the closed economy.

(ii) For intermediate values of the variance in incomes σ, constraint (IRf^H) is binding, and innovating firms block entry from foreign competitors by lowering p^H. Profits net of fixed cost f are lower and q^H is higher than in the closed economy.

(iii) For values of σ sufficiently high, domestic firms can no longer profitably compete with foreign firms in serving the rich households in all differentiated good sectors. In some sectors, high qualities are then imported, the SOE imports higher quality than it exports, and the domestic technological level $A(t+1)$ is decreasing in σ.

Proposition 3 follows from the previous discussions and the technical details in appendix B.2. It carries the central message of this paper that the growth effects of inequality are very different in the SOE when compared to the closed economy. In the closed economy, an increase in σ has a positive effect on growth whenever firms find it optimal to offer separate qualities for the rich and the poor households. By contrast, in an SOE with inequality high enough such that ($\mathrm{IRf}^{\mathrm{H}}$) is binding, firms initially block entry of foreign competitors by lowering p^H, leading to a positive general equilibrium effect on q^H and higher growth. This positive *demand effect* is rooted in the fact that—due to international competition—firms charge smaller mark-ups for high qualities.[37]

As inequality increases further, it is eventually high enough such that some domestic firms no longer find it optimal to serve rich households, implying that foreign competition has a negative *business stealing effect* on innovation and, hence, economic growth. This business stealing effect gets bigger as we further increase σ. This is for two reasons: On

[37] In our model, a smaller mark-up ultimately results in higher demand as mark-ups are fully absorbed by the fixed cost of innovation. Note, however, that the same would also be true with positive profits as long as a smaller mark-up on the side of the firms is not passed on one-for-one to rich households via dividend payments.

the one hand, the higher σ, the larger the share of differentiated goods that the rich import as noted above. On the other hand, in the closed economy, an increase in σ raises the taste for quality of the rich. As discussed above, this price effect is the key driver underlying a demand-driven positive relationship between inequality and growth in the closed economy. The key observation is that this channel is no longer present in the SOE if rich households satisfy their demand for high quality via importing. We summarize these insights in the following corollary.

Corollary 2

In the small open economy, higher inequality can impact growth through

(a) *increased competition that triggers a positive general equilibrium* demand effect *(+) on innovation;*

(b) *a negative* business stealing effect *(-) on growth, when inequality is so high that rich households start satisfying their demand for high quality via importing as domestic firms are no longer able to compete with foreign entrants in all differentiated good sectors.*

Corollary 2 characterizes the two key novel effects of inequality on growth in the SOE that derive from our analysis. Additional effects have to be taken into consideration in richer environments such as knowledge spillovers or feedback effects from lower profits on innovation. We discuss these in section 6.4.

It is interesting to note that an equilibrium with trade, i.e. an equilibrium according to case (iii) of proposition 3, is no longer symmetric. In such an equilibrium, firms in some differentiated good sectors are highly innovative and still serve the rich, while firms in other differentiated good sectors either innovate less to serve the poor or stopped innovating altogether. In either case, there is a 'dual economy' in the SOE, with some sectors being highly innovative while others are lagging behind. Hence, our work shows how non-homothetic demand for quality along with the threat of import competition from abroad can give rise to an endogenous emergence of dual economies in developing countries, even with an ex ante perfectly symmetric set-up.[38] We summarize these insights in the following corollary.

Corollary 3

In an equilibrium with trade, there is a 'dual economy' in the SOE, with some differentiated good sectors being highly innovative, while others are lagging behind.

Whether or not the SOE is in the main scenario of proposition 3, case (iii), depends on

[38] The endogenous emergence of a dual economy in developing countries is related to Porzio (2017), but the mechanisms are very different. Porzio (2017) considers a model with sorting and matching of heterogeneous agents into becoming managers and workers. He shows how a dual economy can arise if firms in developing countries have the opportunity to adopt state-of-the-art technologies from abroad.

inequality as discussed here, but also on its distance to frontier, its trade openness, and aggregate income. We discuss these factors next.

6.3 The role of distance to frontier, trade-costs, and aggregate income

As we have seen, a situation where not all domestic firms are capable of competing against high quality imports is particularly detrimental for innovation in the SOE. In light of these discussions, an ensuing question is when it is more likely that this will be the case. In this respect, we now consider the importance of distance to frontier, trade costs, and aggregate income in turn.

Distance to frontier, inequality, and growth in the SOE

When increasing the technological level in the SOE, keeping constant the income distribution and the technological level in the ROW, the SOE's GDP increases, benefiting both low and high types. In turn, this increases the households' demand for quality. As long as the SOE is sufficiently far from the frontier, however, such an increase in aggregate technology has no effect on innovation and growth in the SOE. This is because equilibrium qualities are a constant-over-time multiple of the technological level inherited from the previous period as shown in corollary 1. This carries over to the SOE as long as it is far from the technological frontier. Specifically, this is the case as long as $\hat{q}^{H,f} \leq \bar{q}^{ROW}(t)$, where here and below we use $\hat{q}^{H,f}$ to denote the optimal import quality of rich households for the level of σ such that domestic firms are just indifferent between innovating or not to serve the rich.

This, however, is no longer true if the SOE is sufficiently close to the world's technological frontier $\bar{q}^{ROW}(t)$. In such case, and for high enough inequality, the rich households' optimal imported quality $q^{H,f}$ as defined in equation (5) is no longer available because it is beyond the technological frontier in the ROW.[39] When this happens, the best import option for rich households is to demand the highest quality in the ROW $\bar{q}^{ROW}(t)$ at marginal cost. Importantly, this implies that innovating domestic firms can compete with foreign firms for higher levels of inequality. More specifically, constraint ($\mathrm{IRf^H}$) is binding for higher levels of inequality only, and whenever it is binding, the outside option $\bar{q}^{ROW}(t)$ has a lower value to the household. We provide further technical details in appendix B.2 and summarize the main insights in the following Corollary.[40]

[39] Note that this must eventually happen at strictly positive distance from the ROW because at the point where domestic firms are just indifferent between serving or not the rich households, the optimal import option of the rich involves strictly higher quality than their domestically offered quality, i.e. it is above the technological level in the SOE as shown in appendix C.6.

[40] Of course, for any distance from the frontier, as we keep on increasing σ, we will always eventually reach a point where the best import option of the rich is to consume $\bar{q}^{ROW}(t)$ and the red dotted curve becomes a straight line in figure 4 in appendix B.2 as well. The point is, that for countries far from the

Corollary 4

Let $\hat{\sigma}(\tau, \bar{A}^{SOE})$ be the highest σ such that domestic firms still find it optimal to serve the rich. Let $\hat{q}^{H,f}$ denote the optimal import quality of rich households in such case. An increase in the level of technology in the SOE, $\bar{q}(t-1)$, has

(i) no effect on equilibrium outcomes and growth in the SOE as long as the SOE is far from the frontier such that $\hat{q}^{H,f} < \bar{q}^{ROW}(t)$;

(ii) increases $\hat{\sigma}(\tau, \bar{A}^{SOE})$ and thus allows firms in the SOE to successfully compete against foreign high-quality providers for higher levels of inequality if the SOE is sufficiently close to the technological frontier such that $\hat{q}^{H,f} \geq \bar{q}^{ROW}(t)$.

Trade costs, inequality, and growth—an infant industry argument

In the previous section, we have seen how a country's technological level can shield domestic innovating firms from international competition, thereby stimulating growth. Trade costs have a similar effect in our model, as ceteris paribus households' best import options are less valuable the higher the trade costs—see equation (6). In turn, this immediately implies that for higher trade costs domestic firms can successfully compete against foreign high-quality providers for larger levels of inequality, i.e. $\hat{\sigma}(\tau, \bar{A}^{SOE})$ as defined in corollary 4 is increasing in τ.

While this is not our main focus, it is nevertheless interesting to note that our work is thus also related to a large literature on dynamic gains from trade and infant industry protection.[41] It shows how lower trade barriers may lead to more quality upgrading in industries (countries) close to the frontier, but discourage quality upgrading in industries (countries) further away from the frontier. This echoes previous findings in the literature (Aghion et al., 2005, 2009; Amiti and Khandelwal, 2013).[42] The key novelty of our set-up is that it highlights how potential gains from trade protection critically depend not only on the distance to frontier, but also on the level of inequality in a country.

frontier as shown in figure 4, this happens only at levels of inequality where domestic firms anyways no longer find it profitable to serve rich households, and it therefore has no effect on their behavior. By contrast, if the SOE is close enough to the frontier, this allows domestic firms to profitably innovate to serve the rich for higher levels of inequality.

[41] See footnote 15.

[42] Aghion et al. (2005) emphasize how competition can increase or decrease innovation incentives depending on the competitive environment of firms, which is related to the firms's technological distance to the frontier. Our model similarly shows that competition can lead to higher innovation or discourage innovation. However, we emphasize how this depends on inequality and, as a consequence, on the demand for quality. Firms lagging behind the world's technological frontier can have high innnovation incentives to be able to compete with foreigh competition if inequality is low and consequently demand for quality is in a range where the domestic firms can successfully compete after innovating. However, with higher inequality the households' demanded level of quality is too high for a lagging domestic firm to be able to profitably cover the high costs of innovation necessary to successfully compete with foreign competition at that level. Therefore, our model shows how domestic firms' innovation incentives and competitiveness depends on the interaction between the distance to the technological frontier, openness, and the level of inequality.

Aggregate income and economic growth

In developing our arguments, we have so far assumed that there is a one-to-one mapping between the level of technology and aggregate income. In line with that view, we also considered a ROW that is perfectly symmetric to the SOE but for its technological level. This is not necessarily the case in oil-rich countries, for example. It is therefore interesting to know how a country's growth prospects change if we increase incomes, holding constant the domestic level of technology. Interestingly, in the closed economy frameworks previously considered in the literature, this will typically boost growth as higher incomes imply higher demand for quality and therefore greater gains from innovation. In our case, this is evident from considering equation (10), which implies that firms respond to higher incomes—and therefore a higher θ^H—by increasing q^H, reflecting the higher willingness to pay for quality on the side of the rich. In the SOE, however, the increase in income also implies that the value of the best import option for the household increases, and this may have an effect on innovation and growth similar to an increase in inequality.[43] In particular, higher windfalls may—for a given level of inequality—imply that the SOE ends up being in scenario (iii) of Proposition 3 where the economy suffers from the negative business stealing effect.[44] In such case, the economy might suffer from a novel negative 'Dutch Disease' type effect of windfall gains on growth. As opposed to the textbook case, the effect here is not centered on intersectoral reallocations,[45] but on the fact that windfall gains through e.g. oil revenues imply that households get richer vis-à-vis the domestic level of technology which may imply that domestic firms find it harder to compete with foreign high-quality providers.

6.4 Discussion

We conclude this section by looking at possible extensions of our model with respect to including more household types and additional channels from inequality to growth in the SOE. We finally discuss policy implications of our analysis.

To carve out the novel causal effects of inequality on growth in the SOE, we have considered an economy with two types of households only, rich and poor. With more than two types, the analysis would be somewhat more involved, but the two effects identified

[43] If innovting firms stopped serving the poor, a proportionate windfall gain in incomes has the exact same effect on innovation and growth as an increase in σ. In a separating equilibrium, a proportionate windfall gain also increases the incomes of the low-types, which impacts (IR^{L}) and, therefore, (IC^{H}).

[44] More generally, windfall gains impact the market size for innovative goods and households' willingness to pay for innovations, and the overall effect on economic growth depends on the relative sizes of these effects and of the 'business stealing effect' through intensified foreign competition.

[45] The basic argument is that an oil boom causes a real appreciation of the domestic currency and therefore decreases an economy's competitiveness in other tradable sectors. If the primary sector has a lower growth potential, this undermines an economy's long-run growth prospects. See e.g. Cordon and Neary (1982).

in Proposition 3 would still be at play and, in fact, typically simultaneously. Consider, for example, the limiting case with a continuum of types. In such case, innovating firms typically find it optimal to exclude a positive mass of households with income $I > \hat{I}$, they then offer increasing contracts in accordance with local (IC) constraints to intermediate types, and pool the highest types at the top to economize on costs of innovation.[46] In the SOE, the very rich satisfy their demand for high quality via importing. An increase in inequality implies that the marginal type who was just indifferent between importing or consuming the highest domestic quality ceteris paribus finds it now beneficial to import. To counteract this negative business stealing effect, innovating firms respond by improving the offer to the highest types, which typically triggers the positive general equilibrium demand effect on innovation and growth. In general, the overall effect of an increase in inequality on innovation incentives depends on how large these two opposing forces are. Yet, in either case the fact that parts of society satisfy their demand for quality via importing is in contrast to the beneficial willingness-to-pay effect of inequality on growth in the closed economy. We test this prediction regarding the differential effect of inequality on growth in open vs closed economies far from the frontier in the empirical section of the paper.

To isolate our main mechanisms of interest, we have further limited ourselves to a demand channel of inequality on growth. Yet, our theory also has implications for two related channels, and while a thorough account is beyond the scope of the current paper, it is nevertheless interesting to briefly discuss the main elements.

On the one hand, we have shown how in the SOE an increase in inequality can induce firms to lower prices, thereby giving rise to the positive general equilibrium demand effect. At the same time, however, this also lowers mark-ups and, hence, profits for innovating firms. With a free-entry condition into innovation, this, in turn, lowers the fixed R&D investment cost in the patent race, f_i. To focus on growth driven by the endogenous quality margin and its relationship to inequality, we assumed that these costs are purely wasteful. An interesting extension would be to assume that higher investments f_i result in a higher innovation rate and, hence, growth. This would be analogous to the assumption typically made in endogenous growth models where higher investments in R&D result in higher propensities to innovate. The fact that ($\mathrm{IRf^H}$) is binding then has a negative *pro-competitive effect* on growth via lower mark-ups and, hence, profits on the side of the innovating firms.[47]

[46] If the distribution of types is without mass points, this has to be the case because it can never be optimal to bear additional innovation costs just to serve households of measure 0.

[47] A simple way of introducing a positive link from f_i to growth into our model would be to endogenize the period length. In particular, we may assume that the fixed cost of investment, f_i, are inversely related to the time it takes a firm to innovate and develop blueprints for higher qualities. If, in addition, a new innovator is only able to build on existing know-how once the preceding innovator starts selling his/her new variety, the time length between two innovations is endogenous and, in particular, depends on the

On the other hand, an oft-stated reason for countries to open to trade with the technologically advanced ROW is to realize knowledge spillovers. One channel through which such spillovers can occur is by learning from sellers (Buera and Oberfield, 2020), and in our model such spillovers may arise because the SOE imports higher quality from abroad. In fact, the imported quality is higher than what would be available domestically in a closed economy as we show in appendix B.2.

In our framework, such spillovers could be included in two ways: First, they could increase the domestic knowledge frontier $\bar{q}(t)$. Second, knowledge spillovers could reduce the cost of innovation. From our discussions in section 6.2, we can directly infer that the latter type of knowledge spillovers reducing innovation costs would, ceteris paribus, increase economic growth in the SOE—see condition (10). Yet, how such spillovers would interact with inequality in shaping growth of the SOE—our main focus of interest—would depend on the details and, in particular, on the magnitude of the spillovers and on how they depend on the gap between imported qualities and the current technology level in the SOE.[48] As opposed to that, when spillovers increase the SOE's technological level, our model would predict possible growth effects over and above the direct spillover effect only if the knwowledge spillovers lifted the SOE to a technological level sufficiently close to the technological frontier, but not if – even with spillovers – the SOE was still technologically lagging to a substantial degree—see section 6.3.

We distinguish developing economies from industrialized ones by their distance to the world's technological frontier only. Certainly, there may be other differences that matter for growth. For example, growth in developing countries can be highly volatile, there may be high entry barriers for firms and it may take more time for a newly developed high-quality variety to be imitated by a competitive fringe. Including such features would make our model more realistic. However, while increasing complexity, they would not change the major underlying mechanisms of interaction between inequality and openness in countries that show a substantial distance to the technological frontier, which is the focus of our work.

Our analysis points to interesting policy implications with respect to opening developing countries for trade with technologically more advanced economies. In our model, the SOE would benefit most if in a situation described by scenario (ii) in Proposition 3, where inequality interacts with foreign competition to increase innovation and growth. Our theory indicates that it depends on the SOE's technological level relative to the

profit potential from successful innovations. Of course, a shorter time to replacement by a new innovator does, in itself, have a negative effect on profits associated with innovations and, hence, growth. Still, we would expect that if ($\mathrm{IRf}^{\mathrm{H}}$) is binding in the SOE and therefore profits are lower when compared to the closed economy, that this has a negative effect on the rate of innovation and, consequently, on growth.

[48]Note that such spillovers are plausibly a non-monotonous function of the technology gap: If the gap is too small or, in the limit, even zero, there is little that can be learned from abroad. On the contrary, if the gap is too large, firms may find it difficult to make use of insights from imported high qualities.

ROW's and on the size of the trade-costs whether the SOE is competitive in this way. Given an SOE's lagging technological level, tariffs could help putting it in a competitive position, and when combined with measures to realize knowledge spillovers this may help bringing the economy to the world's technological frontier. Both types of measures could be strong initially and then phased out as the SOE successfully converges towards the frontier. These policies echo parts of the literature on active industrial policy (e.g. Aghion (2011)) as well as real world policies to capture knowledge spillovers as e.g. pursued by China over the past decades.[49]

7 Growth Regressions

In summary, our theoretical results and the previous discussions suggest that when looking at the data the overall effect of inequality on growth in open economies may not be conclusive. Yet, our theory points to an important negative 'business stealing effect' of inequality on growth in open economies far from the frontier, in line with our stylized facts showing that developing countries do indeed import higher qualities from abroad than what they can produce domestically. Ceteris paribus, the more unequal the income distribution is and the more open the economy, the larger is this effect. Moreover, any additional increase in incomes of rich households and, hence, their willingness to pay for innovation no longer benefits growth in the domestic economy if they satisfy their demand for quality via importing. This is in contrast to the closed economy where higher willingness to pay for quality on the side of the rich leads to more innovation. Our theory therefore suggests that in developing countries, inequality should have a smaller—or more negative—effect on growth in open as opposed to closed economies.

In this section we test whether this theoretical prediction holds up in the data. To this end, we perform two sets of growth regressions: First, industry-level growth regressions using growth in export quality taken from Feenstra and Romalis (2014) as the dependent variable. These are our main regressions as growth in quality is closest to our theoretical model and as some of our variables of interest—distance to frontier and openness—vary at the industry level. Second, to better compare our results to previous work in the literature, we perform standard growth regressions using growth in GDP per capita as the dependent variable.

To perform these regressions, we need data on growth at the country-industry and at the country level, respectively, as well as data on inequality, openness, and distance to frontier

[49]In China, the 'Trade-Technology-for-Market' policy was devised by Deng Xiaoping in the early 1980s. The policy requires foreign companies in strategic sectors to form joint ventures with Chinese state-owned partners – and share their technology as a condition to gain access to the Chinese market. For a recent discussion of this policy with respect to US-China trade relations see e.g. Zhou (2019).

along with other control variables. We begin with introducing our data, before turning to the model specification and results.

7.1 Data

To measure quality upgrading at the country-industry level, we use data on export quality at the SITC4 industry classification level taken from Feenstra and Romalis (2014), i.e. we use export quality to proxy for domestic production capabilities. To measure growth in GDP per capita, we use data on real per capita GDP taken from the Penn World Table (PWT), version 9.0 (Feenstra et al., 2015).

To measure inequality, we use Gini indices in our baseline specification. Gini indices are taken from Solt (2016), as this source combines data from various other databases and makes comparable the Gini indices across countries. We use the Gini index after redistribution. We provide robustness checks using the income shares of the top 10% and top 20%, respectively, in appendix A.3. For these income shares, we rely on data stemming from the World Development Indicators (WDI) (The World Bank, 2018).

Our main theoretical prediction relies on the possibility to import high qualities from abroad, i.e. it applies to countries not at the frontier. To classify a country-industry pair and a country, respectively, as being not at the frontier, we use our data on export quality and GDP per capita from above. We then generate an indicator for whether a country's export quality in a given industry belongs to the bottom 75% within that industry across countries in the year 2000. Analogously, in our country-level regressions, we classify a country as being developing if its GDP per capita in USD belongs to the bottom 75% in the year 2000.[50] We present robustness checks using alternative specifications for distance to the frontier in appendix A.3.

To measure a country's openness in a given industry, we combine data on imports by industry taken from Feenstra and Romalis (2014) with data on nominal GDP taken from the WDI. From this data, we then compute the share of total imports in a given industry and year over GDP and normalize this share by the average share across countries in the same industry to control for cross-industry heterogeneity in size.[51] In our country-level regressions, we use the share of total imports over GDP taken from the WDI. We present robustness checks using alternative measures for openness in appendix A.3.

[50] We use a binary indicator for distance because according to our theory, distance does not matter for countries sufficiently far from the frontier. See section 6.3 for a discussion and appendix A.2 for plots pointing to marked differences between countries at the frontier and from the frontier in terms of the share of industries for which the import quality exceeds the export quality, but much less systematic differences among countries sufficiently far from the frontier.

[51] We use this way to control for average industry-size because output data is not available at the disaggregated country-industry level.

In our regressions without country fixed effects, we further include a series of country-level controls following Barro (2015). We take data for life expectancy, fertility, consumer price inflation, and the terms of trade from the WDI. From Barro and Lee (2013) we take years of schooling for males and females. The PWT provide us with data on investment shares and government consumption shares. Finally, we take a measure of political rights combining data from Freedom House (2016) and Bollen (1980) and standardize it to be between zero and one.

Merging the country level data to the industry specific data gives us a data panel tracking industry-country pairs over time. The industry level export and import data are available for the years 1985–2010. Therefore, our panel spans 25 years, and we use the same years also for the country-level regressions.To increase the variation in the data, we collapse the panel to a five year frequency, such that we have six periods in our panel. For each five year period, we keep the last value available not to lose observations with a data point in 2004 but not in 2005, for example. We exclude resource-rich countries (i.e. countries whose share of resource rents exceeds 20% on average) as well as micro states with a population of less than one million, averaged over all years.[52] The panel then covers 131 countries and a total of 485 industries.[53] Table 2 in appendix A.2 provides descriptive statistics for our dataset.

7.2 Specification and results

Equipped with this data, we estimate the following industry-level regressions.

$$\begin{aligned} \ln\left(\frac{q^s_{x,c,t}}{q^s_{x,c,t-j}}\right) =& \beta_1 \ln(q^s_{x,c,t-j}) + \beta_2 Open^s_{c,t-j} + \beta_3 Ineq_{c,t-j} + \beta_4 Dist^s_c \\ &+ \beta_5[Open^s_{c,t-j} \times Ineq_{c,t-j}] + \beta_6[Open^s_{c,t-j} \times Dist^s_c] \\ &+ \beta_7[Ineq_{c,t-j} \times Dist^s_c] + \beta_8[Open^s_{c,t-j} \times Ineq_{c,t-j} \times Dist^s_c] \\ &+ controls + \epsilon^s_{c,t} \ , \end{aligned} \tag{11}$$

where $q^s_{x,c,t}$ is export quality in country c, year t, and sector (or industry) s. $Open^s_{c,t-j}$ is our measure of openness at the sectoral level, $Ineq_{c,t-j}$ is a measure of inequality, i.e. the Gini index in our baseline specification, and $Dist^s_c$ is an indicator whether sector s in country c has a large distance to the technology frontier. *controls* is a set of control variables which includes industry times year fixed effects and either the large set of country controls following Barro (2015) or country fixed effects. Finally, $\epsilon^s_{c,t}$ is an error term. In

[52]Data on resource rents as a share of GDP are taken from the WDI and data on total population from the PWT.

[53]Note that the total number of industries in the original data is 1646. However, for some countries and industries, there are several measures of units and, hence, some industries appear more than once. We focus on kilograms as the unit measure, since this is the most common in the data. Furthermore, we exclude industries producing homogenous goods, according to the conservative version of the Rauch (1999) index, as quality differs very little in these sectors. This reduces the number of industries to 485.

appendix A.3, we present robustness checks using country times year and country times industry, respectively, fixed effects in our industry-level regressions. As explained above, we use a data panel with a five year frequency (i.e. $j = 5$ and the data are collapsed to a frequency of five years).

To align our results with previous research on growth and inequality, we also estimate the specified regression equation using per capita GDP data at the country level, i.e. we replace quality upgrading by growth in GDP per capita, and use the measures for openness and distance to frontier at the country level as described above. The other control variables are the same as in our industry-level regressions with year fixed effects replacing the industry times year fixed effects.

Our prime interest is in the sum of coefficients β_5 and β_8, which measures how in developing countries the effect of inequality depends on openness to trade. We expect the sum of the coefficients to be negative: Given a country is developing, higher inequality should have a smaller—or more negative—effect on growth in an open than in a closed economy.

We estimate equation (11) using OLS fixed effects regressions. The main results for the different specifications are reported in table 1.

The results show that, as expected, we find conditional convergence for both industry level export quality as well as aggregate GDP growth. For the variables of interest, namely openness, inequality, and level of development, the results for the individual effects are inconclusive. However, as the bottom of the table shows, inequality and openness are jointly inversely related to growth in developing countries. In all specifications, the sum of β_5 and β_8 as specified in equation (11) is negative, and for the industry level regressions as well as for the country regression with country fixed effects it is statistically significant.[54] The results in table 1 therefore provide suggestive evidence that for developing countries openness reduces (or makes more negative) the effect of inequality on quality upgrading (or growth in GDP per capita), as predicted by our theory. Once a country is away from the technological frontier, high inequality and the possibility of the rich class to import high quality goods from abroad reduce innovation incentives for domestic producers. A series of robustness tests confirm these findings. These robustness tests are documented in appendix A.3. Overall, while our empirical exercise reveals only associations in the data, these associations are suggestive evidence for the effects predicted by our theory.

[54]The point estimates in column (4) imply that the effect on 5-year growth in export quality of increasing inequality from the 25th to the 75th percentile is 1.4% lower in developing countries with openness at the 75th percentile than in developing countries with openness at the 25th percentile.

Table 1: Baseline results from panel regressions

Dependent variable in t:	Growth t to $t+1$ in export quality				Growth t to $t+1$ in GDP per capita			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log export quality	-0.73***	-0.73***	-0.67***	-0.75***				
	(0.01)	(0.01)	(0.01)	(0.01)				
Log GDP per capita					-0.09***	-0.09***	-0.48***	-0.51***
					(0.01)	(0.02)	(0.05)	(0.05)
Openness	0.00	0.01	0.01***	-0.01	0.01	-0.11	0.04	-0.25
	(0.00)	(0.02)	(0.00)	(0.01)	(0.01)	(0.12)	(0.03)	(0.27)
Inequality	-0.27***	-0.48	0.50*	1.06***	-0.13	0.53*	1.20**	0.46
	(0.09)	(0.38)	(0.27)	(0.29)	(0.12)	(0.30)	(0.49)	(1.05)
Distance	-0.35***	-0.30*			0.05**	0.40***		
	(0.02)	(0.16)			(0.02)	(0.15)		
Openness ×		-0.01		0.06**		0.37		0.50
Inequality		(0.05)		(0.03)		(0.32)		(0.82)
Openness ×		0.02		0.04***		0.18		0.48*
Distance		(0.03)		(0.01)		(0.13)		(0.28)
Inequality ×		-0.15		-0.94***		-1.00**		-0.04
Distance		(0.44)		(0.10)		(0.40)		(1.31)
Openness ×		-0.06		-0.13***		-0.50		-1.01
Inequality × Distance		(0.06)		(0.02)		(0.35)		(0.85)
Control variables	Yes	Yes	No	No	Yes	Yes	No	No
Industry × Year FE	Yes	Yes	Yes	Yes	No	No	No	No
Year FE	No	No	No	No	Yes	Yes	Yes	Yes
Country FE	No	No	Yes	Yes	No	No	Yes	Yes
Key coefficient		-0.07**		-0.07***		-0.14		-0.50**
Wald test		0.02		0.00		0.44		0.02
Observations	95211	95211	125287	121769	379	379	486	486

Note: Openness is the log of the relative (adjusted) import share (and the country's import share for the country level regressions), Inequality is the Gini index in levels, Distance indicates whether the export quality of an industry was amongst the lower 75% in the year 2000 for the industry level regressions and whether a country's per capita GDP was amongst the lower 75% in the year 2000 for the country level regressions. Control variables is a series of control variables at the country level, as introduced in section 7.1. Key coefficient is the sum of the coefficients for the interaction between Openness and Gini and the interaction between Openness, Gini, and Distance. The Wald test tests whether the sum of the two coefficients is zero and reports the p-value of this test. Standard errors are clustered at the industry×year and country×year level (for industry level analysis) or at the country level (for country level analysis), respectively. Significance at the 10% level is indicated by *, at the 5% level by **, and at the 1% level by ***.

8 Conclusion

In this paper, we analyzed how inequality impacts growth in developing countries in the context of a Schumpeterian model with growth through quality upgrading and non-homothetic demand for quality. Our key insights show that the growth effects of inequality are very different in an open when compared to a closed economy: Higher inequality boosts the willingness to pay for high quality of rich households, which stimulates innovation and growth in the closed economy.

In the open economy, however, this increased taste for quality also makes importing high qualities from abroad more attractive. For low levels of inequality this triggers a positive demand effect on innovation as innovating domestic firms deter entry from foreign competitors by lowering their price on high qualities. For sufficiently high levels of inequality, however, this is no longer profitable and rich households start satisfying their demand for quality via importing, giving rise to a negative business stealing effect of inequality on growth. The size of this effect critically depends on a country's stage of development and its openness to trade. Overall, our theory suggests that in the developing world inequality is more harmful for growth in open as opposed to closed economies. We find empirical support for this theoretical prediction.

While these observations have so far largely gone unnoticed in the literature, we believe that they are of first order importance for our understanding of the growth prospects of developing coutries, and they are of immediate relevance for redistributive and trade policies: In essence, our findings show how a strong (upper-) middle class can be key for sustained growth in the developing world, and how for low levels of development tariffs can have a beneficial effect on growth. The latter point is related to previous findings in the literature (Aghion et al., 2005, 2009; Amiti and Khandelwal, 2013). Our work shows how the benefits from such policies critically depend on inequality.

Our model makes several simplifying assumptions. In developing countries, we may find stronger entry barriers for firms, more macroeconomic volatility, and slower imitation of technological advances by a competitive fringe of firms, for example. Moreover, inequality and openness to trade impact growth through additional channels, including knowledge spillovers, investments in human capital, or political institutions. Incorporating such factors will be an interesting avenue in future work to study the robustness of our findings in more realistic environments. It would also be interesting to analyze how inequality and openness impact growth in countries at the frontier.

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Appendix

A Empirical Appendix

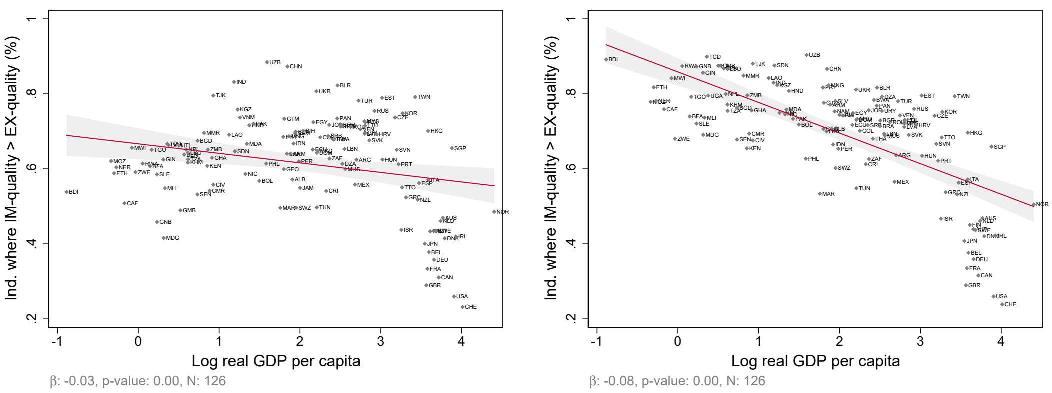
In this part of the appendix, we provide further details on our stylized facts and empirical analysis of sections 2.1 and 7.

A.1 Further details on stylized facts

In this appendix, we provide additional plots supporting our premise that countries sufficiently far from the frontier import high qualities from abroad.

Figure 3: Relative import quality and income

(a) Complete observations **(b) All observations**



Note: Share of industries by country where import quality exceeds export quality. Data is from Feenstra and Romalis (2014) and refers to year 2005. Industries that produce homogenous goods according to the Rauch (1999) classification as well as resource-rich countries and micro states have been excluded. The left panel includes observations for which we have data on both import and export quality, while the right panel keeps all observations and sets quality to zero if quality is not observed.

Figure 3 locates countries in scatter plots with countries' log real GDP per capita on the horizontal and the share of industries for which a country's import quality exceeds its export quality on the vertical axes. The left-hand side panel considers only country-industry pairs for which both import and export qualities are observed. The right-hand side panel includes all country-industry pairs and treats a missing quality (i.e. zero exports or imports in the data) as zero quality. As may be seen from these plots, developing countries import higher quality than they export in a larger fraction of industries when compared to industrialized countries, confirming that the mechanism we consider in this paper is particularly relevant for these countries. Moreover, the difference is particularly pronounced when comparing the richest countries—i.e. those at the frontier—to countries not at the frontier. This is broadly consistent with our theoretical finding that for countries sufficiently far from the frontier such that rich households can import their preferred quality from abroad, increasing distance has no additional effects. The basic patterns are robust to using unit values as a proxy for quality.

A.2 Descriptive statistics

The following table provides descriptive statistics for the variables used in our empirical analysis.

Table 2: Descriptive statistics main variables

Variable	Mean	Std. dev.	Min.	Max.	N
Part I: Macro variables:					
Import share	0.26	0.27	0.00	3.31	704
Real GDP	0.48	1.41	0.00	15.27	704
Population	45.59	148.93	0.73	1340.97	704
Real GDP per capita	12.30	13.44	0.31	81.69	704
Gini	0.39	0.09	0.20	0.62	616
Income share top 20%	0.48	0.08	0.33	0.71	360
Income share top 10%	0.32	0.08	0.19	0.62	360
Life expectancy	66.20	10.73	31.98	82.98	727
Fertility	3.42	1.93	0.96	8.18	727
Schooling (female)	6.78	3.28	0.37	13.23	655
Schooling (male)	7.60	2.83	1.11	13.36	655
Investment share	0.19	0.09	0.01	0.66	704
Government share	0.19	0.09	0.05	0.74	704
Democracy index	0.58	0.36	0.00	1.00	727
CPI inflation	0.50	5.68	-0.04	117.50	628
Terms of trade	1.08	0.51	0.15	5.62	668
Part II: Industry variables:					
Export quality	1.25	1.48	0.00	134.35	191448
Import quality	1.17	0.61	0.03	24.51	263124
Import share	0.00	0.00	0.00	0.26	250597
Import share (adjusted)	0.01	0.03	0.00	1.00	250597

Note: The export and import quality data, as well as the sectoral import shares, are taken from Feenstra and Romalis (2014). The country import shares are taken from the PWT. Real GDP is measured in trillion USD, population in millions and real GDP per capita in 1000 USD. The Gini index is after redistribution. Life expectancy is measured at birth in years, fertility is number of births per woman, schooling is measured in years. The democracy index is standardized between zero and one. Terms of trade is the ratio of the export value index and the import value index.

A.3 Robustness checks for the empirical results

In this section, we present robustness tests to the empirical results presented in section 7.

Table 3 shows the results for the regressions using different specifications for the distance to frontier measure. We vary the threshold level to define an industry or country as being distant from the frontier as well as the reference year. The first two columns use

Table 3: Robustness results: Distance

Dependent variable in t:	Growth t to $t+1$ in export quality				Growth t to $t+1$ in GDP per capita			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log export quality	-0.76***	-0.77***	-0.56***	-0.60***				
	(0.01)	(0.01)	(0.01)	(0.01)				
Log GDP per capita					-0.11***	-0.49***	-0.08***	-0.45***
					(0.02)	(0.05)	(0.01)	(0.04)
Openness	-0.01	-0.01*	0.01	0.01	-0.05	0.09	0.01	-0.02
	(0.02)	(0.01)	(0.02)	(0.01)	(0.05)	(0.09)	(0.15)	(0.30)
Inequality	-0.26	0.90***	-0.90**	0.21	0.26	0.02	-0.00	-0.40
	(0.26)	(0.28)	(0.35)	(0.30)	(0.17)	(0.62)	(0.28)	(1.06)
Distance	-0.27*		-0.11		0.21		0.40**	
	(0.15)		(0.12)		(0.23)		(0.18)	
Openness × Inequality	0.03	0.07***	-0.02	0.01	0.14	-0.32	0.04	-0.28
	(0.04)	(0.02)	(0.05)	(0.02)	(0.12)	(0.22)	(0.41)	(0.81)
Openness × Distance	0.04*	0.06***	0.03	0.03***	0.09	0.34**	0.12	0.36
	(0.02)	(0.01)	(0.02)	(0.00)	(0.11)	(0.16)	(0.17)	(0.31)
Inequality × Distance	-0.23	-0.90***	0.07	-0.28***	-0.61	0.00	-0.89*	0.28
	(0.38)	(0.09)	(0.31)	(0.06)	(0.54)	(1.27)	(0.46)	(1.31)
Openness × Inequality × Distance	-0.10*	-0.17***	-0.07	-0.09***	-0.22	-0.49	-0.33	-0.38
	(0.06)	(0.02)	(0.05)	(0.01)	(0.27)	(0.40)	(0.45)	(0.85)
Control variables	Yes	No	Yes	No	Yes	No	Yes	No
Industry × Year FE	Yes	Yes	Yes	Yes	No	No	No	No
Year FE	No	No	No	No	Yes	Yes	Yes	Yes
Country FE	No	Yes	No	Yes	No	Yes	No	Yes
Key coefficient	-0.07**	-0.10***	-0.09***	-0.08***	-0.08	-0.81**	-0.29	-0.67***
Wald test	0.05	0.00	0.00	0.00	0.76	0.02	0.14	0.01
Observations	95211	121769	59690	80615	379	486	334	425

Note: The specifications are the same as in table 1, except for the measure of Distance. The first two columns use a dummy variable indicating whether the export quality of an industry was amongst the lower 50% in the year 2000. Columns (3) and (4) again use 75% as the threshold but use 1985 as the reference year. Columns (5) to (8) repeat the exercise using GDP per capita and the country level data. Note that the industry level results are robust to defining the distance measure at the country level as well.

a threshold of 50% instead of 75% to classify a sector as not belonging to the technology frontier. In columns (3) and (4) we change the reference year from 2000 to 1985. As the growth rate in export quality has an impact on whether a sector is close to the frontier, we choose the first year of our data as the reference year to alleviate endogeneity problems stemming from potential reverse causality. The remaining columns repeat the exercise again for the country level data. Overall, the results indicate that the way how distance to frontier is defined does not crucially impact our results.

Table 4 provides results for different specifications of the openness measure. Instead of using the continuous adjusted import share, we use a binary variable indicating whether a sector's openness is amongst the 75% highest across countries (first two columns). Furthermore, instead of taking the openness measure for every year, we define openness in the year 2000 and use this measure for all years (columns (3) and (4)). The results hold also

Table 4: Robustness results: Openness

Dependent variable in t:	Growth t to $t+1$ in export quality				Growth t to $t+1$ in GDP per capita			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log export quality	-0.73***	-0.74***	-0.73***	-0.74***				
	(0.01)	(0.01)	(0.01)	(0.01)				
Log GDP per capita					-0.08***	-0.49***	-0.09***	-0.49***
					(0.01)	(0.05)	(0.01)	(0.05)
Openness	0.02	0.28***	-0.00	-0.02**	0.36**	-0.10	-0.03	
	(0.07)	(0.05)	(0.02)	(0.01)	(0.14)	(0.16)	(0.29)	
Inequality	-0.43**	1.37***	-0.41	1.27***	1.17***	-0.99	0.09	-1.64
	(0.21)	(0.29)	(0.35)	(0.32)	(0.35)	(0.70)	(0.49)	(1.03)
Distance	-0.52***		-0.24		0.53***		0.09	
	(0.10)		(0.15)		(0.14)		(0.19)	
Openness ×	-0.02	-0.66***	0.01	0.08***	-0.92**	0.54	0.20	2.82
Inequality	(0.19)	(0.14)	(0.05)	(0.03)	(0.40)	(0.43)	(0.79)	(2.04)
Openness ×	0.11	-0.26***	0.03	0.05***	-0.29*	0.28	0.37	
Distance	(0.08)	(0.06)	(0.02)	(0.01)	(0.17)	(0.18)	(0.51)	
Inequality ×	0.44*	-0.83***	-0.25	-0.89***	-1.33***	3.03***	-0.15	4.46***
Distance	(0.24)	(0.06)	(0.40)	(0.10)	(0.37)	(0.81)	(0.52)	(1.20)
Openness ×	-0.28	0.65***	-0.08	-0.12***	0.76*	-0.96**	-0.97	-8.71**
Inequality × Distance	(0.21)	(0.16)	(0.06)	(0.03)	(0.46)	(0.46)	(1.22)	(3.96)
Control variables	Yes	No	Yes	No	Yes	No	Yes	No
Industry × Year FE	Yes	Yes	Yes	Yes	No	No	No	No
Year FE	No	No	No	No	Yes	Yes	Yes	Yes
Country FE	No	Yes	No	Yes	No	Yes	No	Yes
Key coefficient	-0.30***	-0.01	-0.08***	-0.04**	-0.16	-0.41*	-0.77	-5.89*
Wald test	0.00	0.95	0.01	0.04	0.47	0.06	0.44	0.09
Observations	95211	121769	96136	124441	379	486	379	486

Note: The specifications are the same as in table 1, except for the measure of Openness. Instead of using the continuous measure of the import share, we use a binary variable indicating whether the industry openness is amongst the higher 75% (columns (1) and (2)). In columns (3) and (4), we take the industry's import share in the year 2000 instead of the yearly import share. Columns (5) to (8) repeat the exercise using the country level data. Columns (5) and (6) show the results using a binary variable indicating whether the country's import share is amongst the highest 50%. We use the 50% threshold in order to avoid multicollinearity of the interaction terms. Using the 75% threshold and omitting openness does not substantially change the results. The last two columns use the country's import share in the year 2000. Note that for all specifications using the year 2000 as the reference year we could use 1985 (the first year in our dataset) instead and the results remain robust and become even more pronounced.

if we use 1985 instead of 2000.[55] Columns (5) to (8) repeat the exercise for the country level. The table shows that our main results also do not hinge on the exact definition of openness.

Table 5, repeats the exercise using different measures of inequality. Columns (1) and (2) show the results using the share of incomes going to the top quintile as the inequality measure, while columns (3) and (4) use the share of incomes going to the top decile. Columns (5) to (8) show the results for the country level data. For the sectoral regressions, the estimated key coefficient remains negative in all specifications, while it becomes

[55] Our result is also robust to using country-level instead of country-industry level measures for openness in our industry regressions.

Table 5: Robustness results: Inequality

Dependent variable in t:	Growth t to $t+1$ in export quality				Growth t to $t+1$ in GDP per capita			
Inequality measure in t:	Top 20%		Top 10%		Top 20%		Top 10%	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log export quality	-0.75***	-0.77***	-0.75***	-0.77***				
	(0.01)	(0.01)	(0.01)	(0.01)				
Log GDP per capita					-0.09***	-0.48***	-0.09***	-0.47***
					(0.02)	(0.10)	(0.02)	(0.10)
Openness	0.04	-0.01	0.03	-0.02	-0.09	0.35	-0.06	0.18
	(0.04)	(0.02)	(0.03)	(0.01)	(0.14)	(0.81)	(0.11)	(0.54)
Inequality	-0.58	0.71***	-0.57	1.08***	0.64	-2.17	0.65	-1.79
	(0.55)	(0.25)	(0.59)	(0.27)	(0.76)	(2.00)	(0.96)	(2.30)
Distance	-0.47		-0.45**		0.41		0.29	
	(0.30)		(0.22)		(0.32)		(0.25)	
Openness × Inequality	-0.06	0.06	-0.06	0.11**	0.15	-0.88	0.12	-0.75
	(0.07)	(0.04)	(0.08)	(0.04)	(0.37)	(2.11)	(0.46)	(2.24)
Openness × Distance	-0.01	0.03	-0.01	0.03**	0.13	-0.01	0.09	0.03
	(0.04)	(0.02)	(0.03)	(0.01)	(0.17)	(0.82)	(0.13)	(0.55)
Inequality × Distance	0.04	-0.89***	0.00	-1.29***	-0.79	0.70	-0.79	0.45
	(0.65)	(0.12)	(0.70)	(0.18)	(0.82)	(2.04)	(1.02)	(2.36)
Openness × Inequality × Distance	-0.01	-0.09**	-0.01	-0.15***	-0.25	0.25	-0.21	0.20
	(0.09)	(0.04)	(0.10)	(0.05)	(0.41)	(2.14)	(0.50)	(2.28)
Control variables	Yes	No	Yes	No	Yes	No	Yes	No
Industry × Year FE	Yes	Yes	Yes	Yes	No	No	No	No
Year FE	No	No	No	No	Yes	Yes	Yes	Yes
Country FE	No	Yes	No	Yes	No	Yes	No	Yes
Key coefficient	-0.07*	-0.03	-0.07*	-0.04	-0.10	-0.63**	-0.09	-0.56*
Wald test	0.08	0.29	0.10	0.20	0.53	0.02	0.58	0.06
Observations	53301	60115	53301	60115	222	234	222	234

Note: The specifications are the same as in table 1, except for the measure of Inequality. Instead of the Gini index, we use the income share earned by the top 20% (columns (1), (2), (5), (6)) and the top 10% (columns (3), (4), (7), (8)), respectively.

statistically insignificant once country fixed effects are included. For the country level, the results are robust as well. However, note that it is not straightforward to compare the results using these definitions of inequality to the results with the Gini index, as the sample has changed due to the limited data availability for income shares.

Finally, table 6 shows our industry-level regressions with additional fixed effects. Columns (1) to (4) repeat our main specification from table 1, for convenience. Columns (5) and (6) (columns (7) and (8)) replace the country fixed effects with country times year (country times industry) fixed effects. The estimated key coefficient remains negative in both cases and highly significant for the case of country times year fixed effects.

Table 6: Robustness results: Fixed Effects

Dependent variable in t:	Growth t to $t+1$ in export quality							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log export quality	-0.73***	-0.73***	-0.67***	-0.75***	-0.67***	-0.74***	-1.15***	-1.15***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Openness	0.00	0.01	0.01***	-0.01	0.01***	-0.02*	0.02***	0.05
	(0.00)	(0.02)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.03)
Inequality	-0.27***	-0.48	0.50*	1.06***			0.89***	-0.06
	(0.09)	(0.38)	(0.27)	(0.29)			(0.34)	(0.72)
Distance	-0.35***	-0.30*						
	(0.02)	(0.16)						
Openness × Inequality		-0.01		0.06**		0.08***		-0.08
		(0.05)		(0.03)		(0.03)		(0.07)
Openness × Distance		0.02		0.04***		0.04***		-0.01
		(0.03)		(0.01)		(0.01)		(0.03)
Inequality × Distance		-0.15		-0.94***		-0.94***		0.87
		(0.44)		(0.10)		(0.10)		(0.92)
Openness × Inequality × Distance		-0.06		-0.13***		-0.13***		0.04
		(0.06)		(0.02)		(0.02)		(0.09)
Control variables	Yes	Yes	No	No	No	No	No	No
Industry × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country × Year FE	No	No	No	No	Yes	Yes	No	No
Country × Industry FE	No	No	No	No	No	No	Yes	Yes
Country FE	No	No	Yes	Yes	No	No	No	No
Key coefficient		-0.07**		-0.07***		-0.05***		-0.03
Wald test		0.02		0.00		0.00		0.44
Observations	95211	95211	125287	121769	130310	121769	120433	119859

Note: The specifications are the same as in table 1, except for the selection of the fixed effects as detailed in the table.

B Technical Details on the Small Open Economy

In this appendix, we provide technical details on the small open economy variant of our model.

B.1 Details on (IRf)

In this part of the appendix, we provide further details on (IRf). Specifically, we provide a condition on τ, β and a_q that rules out that low types may find it attractive to import their differentiated goods from abroad, i.e. that constraint (IRf) is binding for the low types. In turn this allows centering the discussions on how the possibility of rich households to import high quality from abroad impacts the growth effects of inequality as shown in section 6.2. The exact condition is provided in the following assumption. It is sufficient but not necessary for our analysis to apply.

Assumption 1

$$\tau \geq \underline{\tau} := \left[\frac{\beta^{\frac{2\beta-1}{\beta}} \left[1 - \frac{1}{a_q}\right]^{1/\beta} \left[a_q(1-\beta)\right]^{\frac{1-\beta}{\beta}}}{1 - \frac{1}{a_q}(1+\beta)} \right]^{\frac{\beta}{2(1-\beta)}}$$

As the following lemma shows, assumption 1 precludes that low types find it optimal to import their differentiated products.

Lemma 3

Let assumption 1 be satisfied. Then constraint (IRf) is either redundant or binding for the high types.

The proof of lemma 3 is given in appendix C.5.

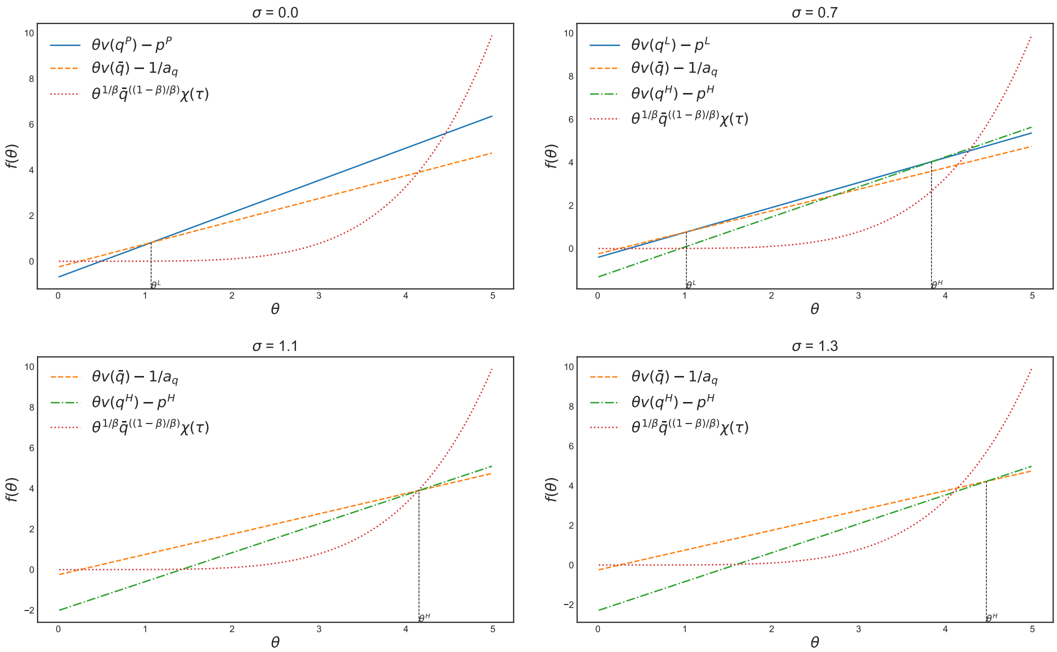
B.2 Inequality and growth in the SOE

In this part of the appendix, we provide a more detailed technical discussion of the effects of inequality on growth in the SOE and also use illustrations to aid the explanations.

Starting from $\sigma = 0$, constraint (IRf) is non-binding for both household types by assumption: This is illustrated in the top-left graph of figure 4. This graph shows a household's payoff from three different consumption choices for the differentiated good as a function of its type θ: The payoff when consuming $\bar{q}(t-1)$, $\theta v(\bar{q}(t-1)) - \frac{1}{a_q}$ (orange dashed line); the payoff when consuming the optimal pooling contract offered by innovating domestic firms, $\theta v(q^P) - p^P$ (blue solid line); and the payoff from the respective best import option, $[\theta]^{\frac{1}{\beta}} [\bar{q}(t-1)]^{\frac{1-\beta}{\beta}} \chi(\tau)$ (red dotted line). Individual rationality for the low types implies that the orange dashed and the blue solid lines intersect at θ^L which is equal to θ^H in this case. Clearly, this intersection lies above the red dotted line, i.e. both types strictly prefer contract (q^P, p^P) over their best import option.

As we increase σ, this does not affect the orange dashed line or the red dotted line in the top-left graph of figure 4. It does, however, decrease θ^L, q^P, and p^P (see proposition 2)—that is, it shifts the blue solid line upwards and makes it less steep in a way such that its intersection with the orange dotted line moves to the left. Most importantly, however, the increase in σ also increases θ^H. As long as ($\mathrm{IRf^H}$) is non-binding, a change in σ trivially has the same effect on growth as in the closed economy: Growth initially declines while still in a pooling equilibrium and eventually increases when σ and, hence, income differences are large enough such that innovating firms find it optimal to separate low types from high types. This separating equilibrium is illustrated in the top-right graph of figure 4. The green dash-dotted line shows a household's payoff from consuming quality q^H, $\theta v(q^H) - p^H$, as a function of θ. As before, ($\mathrm{IR^L}$) implies that the orange dashed and

Figure 4: Illustration of the effect of inequality on innovation in the SOE



Note: The figures illustrate the optimal contracts for different values of σ. The remaining parameter values are $a_q = 4.0$, $\beta = 0.2$, $\lambda = 0.2$, $\bar{q}(t-1) = 1$, and $\tau = 3.0$. Furthermore, $h'(x) = x - 1.0$.

the blue solid lines intersect at θ^L. In addition, (IC$^{\text{H}}$) implies that the blue solid and the green dash-dotted lines intersect at θ^H. As we can observe, both types still prefer their respective contract over their best import option.

However, as we continue to increase σ, θ^H increases further and eventually is high enough such that high types are indifferent between consuming q^H and their best import option. This is illustrated in the bottom-left graph of figure 4, where to clarify the exposition we show a scenario where this indifference occurs only after innovating domestic firms stopped serving the poor. At this point, if we continue to increase σ, constraint (IRf) becomes strictly binding for the high types. As discussed in the main text, this does not have a direct effect on q^H, but induces firms to lower p^H, which has a general equilibrium demand effect on growth. If innovating firms still serve the poor, lowering p^H further relaxes constraint (IC$^{\text{H}}$) and, hence, it allows mitigating the distortion of the low types.[56] Specifically, if (IC$^{\text{H}}$) is slack, innovating firms can earn higher profits by increasing q^L and p^L, holding constant $\theta^L v(q^L) - p^L$ (i.e. guaranteeing that (IR$^{\text{L}}$) remains binding), up to the point where (IC$^{\text{H}}$) is again binding.[57]

[56] In particular, condition (9) trades off the marginal gain of the low types from a higher q^L, $(1-\lambda)\theta^L v'(q_i^L)$, against the marginal cost of increasing q^L, $(1-\lambda)\frac{1}{a_q A}$, and the cost of marginally tightening (IC$^{\text{H}}$), $\lambda\theta^L v'(q_i^L) - \lambda\theta^H v'(q_i^L)$.

[57] If in the closed economy innovating firms just stopped serving the poor, i.e. if the solution to conditions (7) to (10) entailed q^L in the left neighborhood of $\bar{q}(t-1)$, then the relaxation of (IC$^{\text{H}}$) in the SOE may induce firms to continue serving the low types. Otherwise, if firms stopped serving poor households in the no-trade equilibrium, the fact that (IRf) is binding for the high types has no effect on the low-types. In either case, the changes to contract (q^H, p^H) are as described above.

As we keep increasing σ and, hence, θ^H, ($\mathrm{IRf^H}$) tightens further,[58] and this has the same qualitative effect on q^H and p^H as described previously. Eventually, however, θ^H is so high and, hence, foreign competition fierce enough such that it is no longer profitable for firms in all domestic good sectors to serve the rich.[59] Rich households start importing some differentiated goods from abroad, and the imported qualities are higher than the qualities they buy from innovative domestic firms in other differentiated good sectors as the following proposition shows.

Proposition 4

When firms in the SOE are just indifferent between innovating or not to serve rich households, the quality they would offer to the rich households is strictly lower than the quality of their best import option.

The proof of proposition 4 is given in appendix C.6.

Proposition 4 implies that the share of differentiated good sectors in which rich households satisfy their demand for quality via importing increases gradually as we keep on increasing σ.[60] This share is determined by the requirement that it must induce a marginal decrease in θ^H such that it exactly makes domestic firms again indifferent between innovating or not to serve the rich households, because otherwise it cannot be that only a subset of firms innovates.

If a domestic firm no longer finds it optimal to serve rich households, it may either stop innovating altogether or keep innovating to serve the poor, depending on parameter values. In either case, $\bar{q}_i(t)$ in the importing sectors is lower when compared to the closed economy

[58] In the case where firms stopped serving the poor this follows immediately from the fact that the value of the contract for the rich in the closed economy is determined by the orange dashed line in the bottom-right graph of figure 4. The distance between this straight line and the value of the best import option as given by the strictly convex red dotted line is increasing as we increase θ beyond their intersection point.

[59] To see that ($\mathrm{IRf^H}$) must eventually be strictly binding, note that in the closed economy the value of contract (q^H, p^H) for the rich is in figure 4 bounded from above by a straight line. In particular, if firms already stopped serving the poor, firms optimally set prices such that ($\mathrm{IR^H}$) holds with equality, which implies that the value of the contract is just on the orange dashed line. If they are still serving the poor, the value of the contract is determined by the blue solid line which changes as we change σ. Note, however, that it is bounded from above by a line with intercept $-\frac{1}{a_q}$ and slope $v(\hat{q}^P)$, where we use $\hat{q}^P$ to denote the optimal quality in the pooling equilibrium with $\sigma = 0$. For this line and the orange dashed line, respectively, there exists a threshold $\bar{\theta}$ such that the distance between the convex red dotted curve and the respective straight line is such that high types can only be made indifferent between the domestic contract and the best import option by setting $p^H = \frac{q^H}{a_q}$, the variable cost of producing q^H, and it is for sure not profitable to serve the rich.

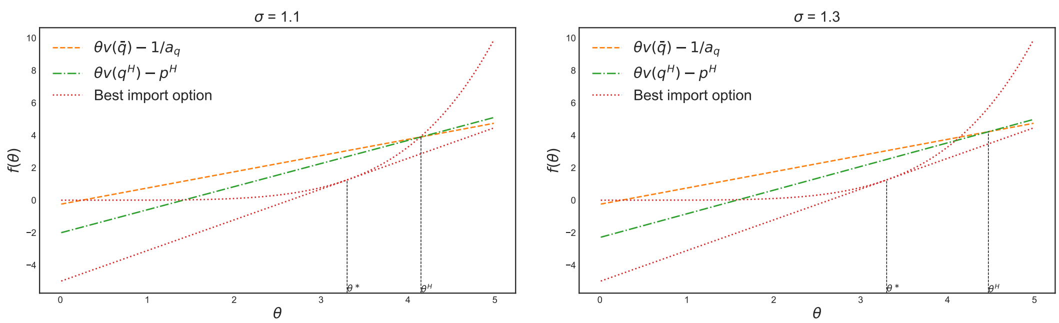
[60] This can be shown by contradiction. In particular, note that proposition 4 in combination with the fact that (IRf) holds with equality for the high types implies that not only the quality of the best import option, but also its price is higher when compared to the offer by innovating domestic firms to the high types. Hence, if rich households switch from consuming a differentiated good domestically to importing it, this has a negative effect on θ^H. Now, let $\tilde{\sigma}$ be the level of inequality for which domestic innovating firms are just indifferent between serving or not the rich households if all other firms are doing so. Suppose, by contradiction, that starting from $\tilde{\sigma}$, a marginal increase in σ induced all firms—or, for that matter, any set of positive measure of firms—to stop serving the rich. Then, by the above, this would trigger a discrete drop in θ^H, a contradiction to not serving the rich being optimal.

and $A(t+1)$ is decreasing vis-à-vis the closed economy as we increase further σ.

B.3 Competitiveness of the SOE close to the frontier

In this appendix, we provide further details on the case where the SOE is sufficiently close to the world's technological frontier $\bar{q}^{ROW}(t)$ such that for high enough levels of inequality, the rich households' optimal imported quality $q^{H,f}$ as defined in equation (5) is no longer available because it is beyond the current technological frontier in the ROW. When this happens, the best import option for rich households is to demand the highest quality in the ROW, $\bar{q}^{ROW}(t)$, at marginal cost. In terms of figure 4, this implies that the red dotted line changes: It will stay the same up to the level of θ^* for which the best import option at marginal cost is exactly $\bar{q}^{ROW}(t)$, and will become a straight line thereafter, as shown in figure 5. This straight line is tangential to the red dotted curve at θ^* and is everywhere below this line. Importantly, this implies that innovating domestic firms can compete with foreign firms for higher levels of inequality. More specifically, constraint ($\mathrm{IRf}^{\mathrm{H}}$) is binding for higher levels of inequality only, and whenever it is binding, the outside option has a lower value to the household. This is shown in figure 5 for the case where a household with $\theta^* = 3.3$ just finds it optimal to import $q^{H,f} = \bar{q}^{ROW}(t)$. The best import option for a household as a function of θ is now indicated by the dark red dotted line. Clearly, for $\sigma = 1.1$, the level of inequality where ($\mathrm{IRf}^{\mathrm{H}}$) was just binding in figure 4, this constraint is no longer binding (left panel), because the rich can now do no better than importing $\bar{q}^{ROW}(t) < q^{H,f}$ at marginal cost and this carries lower value. The same is still true for even higher levels of inequality (right panel).

Figure 5: Illustration of the effect of inequality on innovation in an SOE closer to the frontier



Note: The figures illustrate the values of different consumption options as a function of θ for different values of σ. The remaining parameter values are $a_q = 4.0$, $\beta = 0.2$, $\lambda = 0.2$, $\bar{q}(t-1) = 1$, and $\tau = 3.0$. Furthermore, $h'(x) = x - 1.0$.

C Proofs

C.1 Proof of lemma 1

We show a variant of lemma 1 with an arbitrary set Θ of types. The case with two types then follows immediately as a special case.

Lemma 1′

The decision problem of innovating firm i is equivalent to:[61]

$$\max_{\{q_i(\theta),p_i(\theta)\}_{\theta\in\Theta},\bar{q}_i(t)} \quad \int_{\theta\in\Theta}\left[p_i(\theta)-\frac{1}{a_q A}q_i(\theta)\right] f_\theta(\theta)\,d\theta - h\left(\frac{\bar{q}_i(t)}{\bar{q}_i(t-1)}\right)$$

$$\text{s.t.} \quad \theta v(q_i(\theta)) - p_i(\theta) \geq \text{argmax}_{q\in[0,\bar{q}_i(t-1)]}\left\{\theta v(q) - \frac{1}{a_q A}q\right\}\ , \quad \forall\,\theta\in\Theta \tag{IR}$$

$$\theta v(q_i(\theta)) - p_i(\theta) = \text{argmax}_{\hat{\theta}\in\Theta}\left\{\theta v(q_i(\hat{\theta})) - p_i(\hat{\theta})\right\}\ , \quad \forall\,\theta\in\Theta \tag{IC}$$

$$q_i(\theta) \leq \bar{q}_i(t), \quad \forall\,\theta\in\Theta\,,$$

where $v(q) := q^{1-\beta}$ and where the firm considers type $\theta^h := \frac{p_z z^h}{\beta Q^h}$, $Q^h := \int_0^1 {q_i^h}^{1-\beta}\,di$, of household $h\in\{L,H\}$ as exogenously given. θ^h is private knowledge to the households and is distributed according to $f_\theta(\theta)$ with support Θ, with this probability density function (pdf) being common knowledge.

Proof To show the desired result, we proceed in three steps.

1. In every period household h chooses q_i^h and z^h to maximize

$$\max_{\{q_i^h\}_{i\in[0,1]},z^h} \quad \left[\int_0^1 {q_i^h}^{1-\beta}\,di\right] {z^h}^\beta$$
$$\text{s.t.} \quad \int_0^1 p_i(q_i^h)\,di + p_z z^h \leq I^h\,,$$

where I^h denotes per-period income of household h which equals total expenditure of household h in the current period. The separability of the instantaneous utility function in combination with the fact that each differentiated good has measure 0 imply that the household chooses q_i^h to maximize

$$\max_{q_i^h} \quad {q_i^h}^{1-\beta}{z^h}^\beta - \mu^h p_i(q_i^h)\,, \tag{C.1}$$

where μ^h is the shadow value of income which, by the envelope theorem, is equal to

$$\mu^h = \frac{du^h(\cdot)}{dI^h} = \frac{\frac{\partial u^h}{\partial z^h}}{p_z} \tag{C.2}$$

$$= \frac{\beta Q^h {z^h}^{\beta-1}}{p_z}\ . \tag{C.3}$$

[61] With a slight abuse of notation we use the integral sign to denote a finite sum in case of a discrete set Θ.

Substituting equation (C.2) for μ^h in decision problem (C.1), we get

$$\max_{q_i^h} \quad {q_i^h}^{1-\beta} {z^h}^{\beta} - \frac{\beta Q^h {z^h}^{\beta-1}}{p_z} p_i(q_i^h)\,,$$

which is equivalent to

$$\max_{q_i^h} \quad {q_i^h}^{1-\beta} \frac{z^h p_z}{\beta Q^h} - p_i(q_i^h)\,.$$

2. From the perspective of innovating firm i, $\theta^h := \frac{z^h p_z}{Q^h \beta}$ is a sufficient statistic for household characteristics, which is exogenous to the firm and observed only by the household. θ is distributed according to $f_\theta(\theta)$, which depends on the full general equilibrium in the economy.

Let Θ denote the set of pairwise distinct elements in $\left\{\theta^h\right\}_{h\in[0,1]}$. Then, by the revelation principle (cf. e.g. Mas-Colell et al. (1995, Proposition 23.C.1)), the innovating firm can limit attention to truthful revelation mechanisms, i.e. for each $\theta \in \Theta$ a quality-price bundle $(q_i(\theta), p_i(\theta))$ such that households find it optimal to truthfully reveal their type, that is

$$\theta v(q_i(\theta)) - p_i(\theta) = \text{argmax}_{\hat\theta\in\Theta} \left\{\theta v(q_i(\hat\theta)) - p_i(\hat\theta)\right\}\ , \quad \forall\, \theta \in \Theta\ , \tag{IC}$$

where $v(q_i) = {q_i}^{1-\beta}$ and $p_i(\theta) := p_i(q_i(\theta))$.

3. The competitive fringe implies that all qualities $q_i \leq \bar q_i(t-1)$ are offered at marginal cost, which, in turn, implies that every household must weakly prefer its offered contract $(q_i(\theta^h), p_i(\theta^h))$ to its best choice among all qualities $q \leq \bar q_i(t-1)$

$$\theta v(q_i(\theta)) - p_i(\theta) \geq \text{argmax}_{q\in[0,\bar q_i(t-1)]} \left\{\theta v(q) - \frac{1}{a_q A} q\right\}\ , \quad \forall\, \theta \in \Theta\ . \tag{IR}$$

The lemma then follows from combining the above with the firm's profit function (3), from noting that total demand for quality $\hat q$ is equal to the mass of households of type $\{\theta \in \Theta : q(\theta) = \hat q\}$, and from taking into account the endogenous choice of $\bar q_i(t)$.

□

C.2 Proof of lemma 2

Consider any two types $\theta^H, \theta^L \in \Theta$. We show that

$$\theta^H > \theta^L \quad \Rightarrow \quad I^H > I^L \tag{i}$$

$$\theta^H = \theta^L \quad \Rightarrow \quad I^H = I^L\ . \tag{ii}$$

The result then follows.

(i) The following conditions are necessary for incentive compatibility for both types:

$$\theta^H v(q_i(\theta^H)) - p_i(\theta^H) \geq \theta^H v(q_i(\theta^L)) - p_i(\theta^L) \tag{IC^H}$$

$$\theta^L v(q_i(\theta^L)) - p_i(\theta^L) \geq \theta^L v(q_i(\theta^H)) - p_i(\theta^H) \ . \tag{IC^L}$$

Rearranging terms and combining the two conditions, we get

$$\theta^H \left[v(q_i(\theta^H)) - v(q_i(\theta^L))\right] \geq \theta^L \left[v(q_i(\theta^H)) - v(q_i(\theta^L))\right] \ .$$

Using $\theta^H > \theta^L$ along with the fact that $v'(\cdot) > 0$, we get

$$q_i(\theta^H) \geq q_i(\theta^L) \ \forall \, i \in [0,1] \ ,$$

and, hence

$$Q^H = \int_0^1 \left(q_i(\theta^H)\right)^{1-\beta} di \geq \int_0^1 \left(q_i(\theta^L)\right)^{1-\beta} di = Q^L \ . \tag{C.4}$$

Moreover, incentive compatibility requires that $p_i(\theta^H) \geq p_i(\theta^L) \ \forall \, i \in [0,1]$, implying that

$$\int_0^1 p_i(\theta^H) \, di \geq \int_0^1 p_i(\theta^L) \, di \ . \tag{C.5}$$

Finally, by the monotonicity of households' preferences, the budget constraint always holds with equality, i.e. we have

$$p_z z^h = I^h - \int_0^1 p_i(\theta^h) \, di \quad \forall \, h \in [0,1] \ . \tag{C.6}$$

Combining (C.4), (C.5), and (C.6) with the definition of θ, we conclude

$$\theta^H > \theta^L \quad \Rightarrow \quad I^H > I^L \ .$$

(ii) It remains to show that

$$\theta^H = \theta^L \quad \Rightarrow \quad I^H = I^L \ .$$

We proceed by contradiction. Suppose there exist two types of households with $I^H > I^L$ satisfying $\theta^H = \theta^L$. Then it must be that $Q^H > Q^L$ and that $\int_0^1 p_i(\theta^H) \, di > \int_0^1 p_i(\theta^L) \, di$. Hence, for some measurable subset $\hat{\mathcal{I}} \subseteq [0,1]$ we must have that

$$q_i(\theta^H) > q_i(\theta^L) \quad \forall \, i \in \hat{\mathcal{I}} \ ,$$

where incentive compatibility for both H and L requires

$$\theta^h v(q_i(\theta^H)) - p_i(\theta^H) = \theta^h v(q_i(\theta^L)) - p_i(\theta^L) \quad \forall \, i \in [0,1], \ h \in \{L, H\} \ . \tag{C.7}$$

This, however, contradicts profit maximization by innovating firms $i \in \hat{\mathcal{I}}$. To see this, note that for firm i to offer two distinct contracts to one type of households, both contracts must yield the same profit to the firm. Consider, for concreteness, the case of $q_i(\theta^H) < \bar{q}_i(t)$.[62] Then, we must have

$$p_i(\theta^H) - p_i(\theta^L) = \frac{1}{a_q A}\left(q_i(\theta^H) - q_i(\theta^L)\right) \ . \tag{C.8}$$

(C.7), (C.8), and the concavity of $v(\cdot)$ imply that for every $\tilde{q}_i \in (q_i(\theta^L), q_i(\theta^H))$ there exists a $\tilde{p}_i \in (p_i(\theta^L), p_i(\theta^H))$ such that

$$\theta^h v(q_i(\theta^L)) - p_i(\theta^L) = \theta^h v(\tilde{q}_i) - \tilde{p}_i \ , \quad h \in \{L, H\}$$

and

$$\tilde{p}_i - p_i(\theta^L) > \frac{1}{a_q A}\left(\tilde{q}_i - q_i(\theta^L)\right) \ .$$

The contract $(\tilde{q}_i, \tilde{p}_i)$ yields higher profits for the firm than both $(q_i(\theta^H), p_i(\theta^H))$ and $(q_i(\theta^L), p_i(\theta^L))$. It satisfies (IC) and (IR) for households L, H. Moreover, it weakly relaxes (IC) to all other households because it is less preferred than $(q_i(\theta^L), p_i(\theta^L))$ by all types $\theta < \theta^L$ and less preferred than $(q_i(\theta^H), p_i(\theta^H))$ by all types $\theta > \theta^H$. Hence, offering $(q_i(\theta^H), p_i(\theta^H))$ and $(q_i(\theta^L), p_i(\theta^L))$ cannot be profit maximizing.

□

C.3 Proof of proposition 1

We first state the formal version of Proposition 1, which we prove in the following.

Proposition 1′

There is a unique equilibrium satisfying for $h = \{H, L\}$: $q_i^{h^e} = q^{h^e}$ and $p_i^{h^e} = p^{h^e}$ $\forall\, i \in [0,1]$. Depending on parameter values, this equilibrium can be characterized according to one of the following cases:

(i) $\boldsymbol{I^L \leq I^H \leq \hat{I}}$ **:**
$q^{L^e} = (1-\beta)a_q A I^L$, $p^{L^e} = \frac{1}{a_q A} q^{L^e}$
$q^{H^e} = (1-\beta)a_q A I^H$, $p^{H^e} = \frac{1}{a_q A} q^{H^e}$

(ii) $\boldsymbol{I^H > \hat{I} \geq I^L}$ **:**
$q^{L^e} = (1-\beta)a_q A I^L$, $p^{L^e} = \frac{1}{a_q A} q^{L^e}$
$q^{H^e} > \bar{q}(t-1)$ and p^{H^e} are the unique solutions to:

$$\frac{I^H - p^{H^e}}{\beta}\left[1 - \left(\frac{\bar{q}(t-1)}{q^{H^e}}\right)^{1-\beta}\right] + \frac{1}{a_q} = p^{H^e}$$

$$\lambda \frac{1-\beta}{\beta}\left(I^H - p^{H^e}\right) - \lambda \frac{1}{a_q} \frac{q^{H^e}}{\bar{q}(t-1)} - \frac{q^{H^e}}{\bar{q}(t-1)} h'\left(\frac{q^{H^e}}{\bar{q}(t-1)}\right) = 0$$

(iii) $\boldsymbol{I^H \geq I^L > \hat{I}}$ **:**

[62] It is straightforward to extend the argument to the case of $q_i(\theta^H) = \bar{q}_i(t)$.

(A) If the solution to the system of equations in part (B) involves $q^L \leq \bar{q}(t-1)$, there is a separating equilibrium with $q^{L^e} = \bar{q}(t-1), p^{L^e} = \frac{1}{a_q}$ and where q^{H^e}, p^{H^e} are the solutions to the equations as shown in (ii).

(B) There is a separating equilibrium where q^{L^e}, p^{L^e}, q^{H^e}, and p^{H^e} are the unique solutions to:

$$\frac{I^L - p^{L^e}}{\beta}\left[1 - \left(\frac{\bar{q}(t-1)}{q^{L^e}}\right)^{1-\beta}\right] + \frac{1}{a_q} = p^{L^e}$$

$$\frac{I^H - p^{H^e}}{\beta}\left[1 - \left(\frac{q^{L^e}}{q^{H^e}}\right)^{1-\beta}\right] + p^{L^e} = p^{H^e}$$

$$I^L - \lambda\left(I^H - p^{H^e}\right)\left(\frac{q^{L^e}}{q^{H^e}}\right)^{1-\beta} - (1-\lambda)\frac{\beta}{(1-\beta)a_q}\frac{q^{L^e}}{\bar{q}(t-1)} = p^{L^e}$$

$$\lambda\frac{1-\beta}{\beta}\left(I^H - p^{H^e}\right) - \lambda\frac{1}{a_q}\frac{q^{H^e}}{\bar{q}(t-1)} - \frac{q^{H^e}}{\bar{q}(t-1)}h'\left(\frac{q^{H^e}}{\bar{q}(t-1)}\right) = 0\ .$$

(C) If the solution to the system of equations in part (B) involves $q^L \geq q^H$, there is a pooling equilibrium, i.e. $q^{L^e} = q^{H^e} = q^{P^e}$ and $p^{L^e} = p^{H^e} = p^{P^e}$ which are the unique solutions to:

$$\frac{I^L - p^{P^e}}{\beta}\left[1 - \left(\frac{\bar{q}(t-1)}{q^{P^e}}\right)^{1-\beta}\right] + \frac{1}{a_q} = p^{P^e}$$

$$\frac{1-\beta}{\beta}\left(I^L - p^{P^e}\right) - \frac{1}{a_q}\frac{q^{P^e}}{\bar{q}(t-1)} - \frac{q^{P^e}}{\bar{q}(t-1)}h'\left(\frac{q^{P^e}}{\bar{q}(t-1)}\right) = 0\ .$$

We begin the proof of the proposition with a preliminary observation and then prove each part of proposition 1′ in turn.

Lemma 4

The equilibrium price of quality q_i^h, $h \in \{L, H\}$, of any differentiated good $i \in [0,1]$ is never below its marginal cost of production, i.e.

$$p_i^h \geq \frac{q_i^h}{a_q A}\ , \quad h \in \{L, H\}.$$

Proof We proceed by contradiction. Suppose innovating firm i offers contracts (q_i^h, p_i^h) and $(q_i^{\hat{h}}, p_i^{\hat{h}})$, $h \neq \hat{h} \in \{L, H\}$, and where $p_i^h < \frac{q_i^h}{a_q A}$ and $p_i^{\hat{h}} \geq \frac{q_i^{\hat{h}}}{a_q A}$.[63] Contract (q_i^h, p_i^h) is loss making for firm i. Consider the following variant to these contracts:

$$\tilde{q}_i^{\hat{h}} = q_i^{\hat{h}}$$
$$\tilde{p}_i^{\hat{h}} = p_i^{\hat{h}}$$

[63] Note that the firm will never price both contracts below marginal cost because this would imply that it is making losses and staying out of business and making zero profits is always an option for the firm.

and

$$\tilde{q}_i^h = \underset{q\in\{[0,\bar{q}(t-1)],q_i^h,q_i^{\hat{h}}\}}{argmax} \quad \{\theta^h v(q) - \tilde{p}_i^h\}$$

$$s.t. \quad \tilde{p}_i^h = \begin{cases} \frac{\tilde{q}_i^h}{a_q A}, & \text{if } \tilde{q}_i^h \in \{[0,\bar{q}(t-1)], q_i^h\} \\ \tilde{p}_i^{\hat{h}}, & \text{if } \tilde{q}_i^h = \tilde{q}_i^{\hat{h}} \end{cases} .$$

By construction, contract $(\tilde{q}_i^h, \tilde{p}_i^h)$ satisfies (IR) and (IC) for households h. Moreover, as either $\tilde{q}_i^h = q_i^h$ and $\tilde{p}_i^h > p_i^h$, or $(\tilde{q}_i^h, \tilde{p}_i^h)$ is a contract that has already been available previously, contract $(\tilde{q}_i^{\hat{h}}, \tilde{p}_i^{\hat{h}})$ satisfies (IR) and (IC) for household $\hat{h}$. Yet, contracts $(\tilde{q}_i^h, \tilde{p}_i^h)$, $(\tilde{q}_i^{\hat{h}}, \tilde{p}_i^{\hat{h}})$ yield strictly larger profits to firm i when compared to contracts (q_i^h, p_i^h) and $(q_i^{\hat{h}}, p_i^{\hat{h}})$, a contradiction to the latter being profit maximizing.

□

(i) Suppose all qualities are offered at marginal cost. Then household $h \in \{H, L\}$ maximizes its instantaneous utility (1) subject to

$$\int_0^1 q_i^h \frac{1}{a_q A}\, di + z^h \frac{1}{a_z A} = I^h .$$

Standard derivations then imply that $q_i^h = q^h \; \forall\, i \in [0,1]$ and that

$$q^h \frac{1}{a_q A} = (1-\beta) I^h . \tag{C.9}$$

Now, the solution to (C.9) is household h's consumed quality unless this quality level is not available or some other quality is sold at a price below marginal cost. By lemma 4, the latter will never happen in equilibrium. Moreover, the competitive fringe for pre-existing qualities implies that qualities $q_i \leq \bar{q}(t-1)$ are offered at marginal cost in equilibrium. The result then follows from observing that the solution according to (C.9) is increasing in I^h, from noting that a household with income $\hat{I}$ would just find it optimal to consume quality $\bar{q}(t-1)$ if all qualities were offered at marginal cost, and from rearranging terms.

(ii) From the above we know that for all differentiated goods we have: $q^{Le} = (1-\beta) a_q A I^L$ and $p^{Le} = \frac{1}{a_q A} q^{Le}$ and that household H's preferred option among freely available qualities is $\bar{q}(t-1)$. Moreover, it is never optimal for the firm to upgrade quality more than what is needed to serve the high types, i.e. we have $\bar{q}_i(t) = \max\{\bar{q}(t-1), q_i^H\}$. Hence, firm i's decision problem simplifies to

$$\max_{q_i^H, p_i^H} \quad \lambda \left[p_i^H - \frac{1}{a_q A} q_i^H \right] - h\left(\frac{q_i^H}{\bar{q}(t-1)} \right)$$

$$\text{s.t.} \quad \theta^H v(q_i^H) - p_i^H \geq \theta^H v(\bar{q}(t-1)) - \frac{1}{a_q A} \bar{q}(t-1) . \tag{IR$^\mathrm{H}$}$$

As the firm's profits are strictly increasing in p_i^H, (IR$^{\mathrm{H}}$) always holds with equality in equilibrium. Rearranging (IR$^{\mathrm{H}}$), substituting in for p_i^H in the objective, and differentiating with respect to q_i^H, we get the following necessary conditions for profit maximization:

$$\theta^H v(q_i^H) - \theta^H v(\bar{q}(t-1)) + \frac{1}{a_q A}\bar{q}(t-1) = p_i^H \tag{IR$^{\mathrm{H}}$}$$

$$\lambda\theta^H v'(q_i^H) - \lambda\frac{1}{a_q A} - \frac{1}{\bar{q}(t-1)}h'\left(\frac{q_i^H}{\bar{q}(t-1)}\right) = 0\ . \tag{C.10}$$

Note that for every $\theta^H > 0$, the first order conditions (IR$^{\mathrm{H}}$) and (C.10) have at most one solution, implying that any equilibrium has to be symmetric across differentiated goods. Using the symmetry, $A = \bar{q}(t-1)$, the fact that $I^H - p^H = p_z z^H$, the definitions of θ and $v(\cdot)$, and rearranging terms, we get

$$\frac{I^H - p^H}{\beta}\left[1 - \left(\frac{\bar{q}(t-1)}{q^H}\right)^{1-\beta}\right] + \frac{1}{a_q} = p^H \tag{C.11}$$

$$\lambda\frac{1-\beta}{\beta}\left(I^H - p^H\right) - \lambda\frac{1}{a_q}\frac{q^H}{\bar{q}(t-1)} - \frac{q^H}{\bar{q}(t-1)}h'\left(\frac{q^H}{\bar{q}(t-1)}\right) = 0\ , \tag{C.12}$$

which are the expressions shown in proposition 1′. Finally, to see that these equations have a unique solution and that this solution involves $q^{H^e} > \bar{q}(t-1)$, observe that (C.11) describes an increasing relationship between p^H and q^H starting from $p^H = \frac{1}{a_q}$ and $q^H = \bar{q}(t-1)$ and converging to $p^H = \frac{I^H}{1+\beta} + \frac{\beta}{(1+\beta)a_q}$ as $q^H \to \infty$, while (C.12) describes a decreasing relationship between p^H and q^H starting from $p^H = I^H - \frac{\beta}{(1-\beta)a_q}$ and $q^H = \bar{q}(t-1)$, and reaching $p^H = 0$ at the solution of

$$\frac{1-\beta}{\beta}\lambda I^H = \frac{\lambda}{a_q}\frac{\hat{q}^H}{\bar{q}(t-1)} + \frac{\hat{q}^H}{\bar{q}(t-1)}h'\left(\frac{\hat{q}^H}{\bar{q}(t-1)}\right)\ .$$

The result then follows from $I^H > \frac{1}{a_q(1-\beta)}$.

(iii) We show existence and uniqueness of the equilibrium by construction. In particular, we follow the standard procedure for addressing this optimization problem, i.e. we eliminate (IR$^{\mathrm{H}}$) as it is redundant and consider the firm's maximization problem ignoring (IC$^{\mathrm{L}}$). Noting further that (IR$^{\mathrm{L}}$) and (IC$^{\mathrm{H}}$) are always binding,[64] this yields the following first order conditions for profit maximization:

$$\theta^L\left(v(q_i^L) - v(\bar{q}(t-1))\right) + \frac{1}{a_q} = p_i^L \tag{C.13}$$

$$\theta^H\left(v(q_i^H) - v(q_i^L)\right) + p_i^L = p_i^H \tag{C.14}$$

$$\theta^L v'(q_i^L) - \lambda\theta^H v'(q_i^L) - (1-\lambda)\frac{1}{a_q A} \leq 0 \tag{C.15}$$

$$\lambda\theta^H v'(q_i^H) - \lambda\frac{1}{a_q A} - h'\left(\frac{q_i^H}{\bar{q}(t-1)}\right)\frac{1}{\bar{q}(t-1)} = 0\ , \tag{C.16}$$

[64] If not, the firm could increase profits by raising p^L and / or p^H.

with the complementary slackness condition for (C.15) being

$$\left[\theta^L v'(q_i^L) - \lambda\theta^H v'(q_i^L) - (1-\lambda)\frac{1}{a_q A}\right]\left[q_i^L - \bar{q}(t-1)\right] = 0 \; . \tag{C.17}$$

For θ^L and θ^H given, these equations have exactly one solution. If this solution implies $q_i^H \geq q_i^L$, it characterizes the uniquely optimal choice of firm i. If it involves $q_i^H < q_i^L$, then the uniquely optimal choice is instead to pool consumers.[65] We will get back to this point later and characterize the separating equilibrium first, if it exists.

Note first that the fact that for θ^L and θ^H given, equations (C.13) to (C.17) have a unique solution implies that there can only exist a symmetric separating equilibrium. This equilibrium can be derived by the following algorithm that takes into account the endogeneity of θ^h, $h \in \{L, H\}$, with respect to the equilibrium outcomes:

(1) For every $\hat{q}^L$, there is a unique $\hat{p}^L$ satisfying (C.13). For $\hat{q}^L$ and $\hat{p}^L$ given, (C.14) describes a monotonously increasing relation between p^H and q^H, starting at $\hat{q}^H = \hat{q}^L$ and $\hat{p}^H = \hat{p}^L$ and converging to $\hat{p}^H = \frac{I^H + \hat{p}^L \beta}{1+\beta}$ as $\hat{q}^H \to \infty$. (C.16), on the other hand, describes a monotonously decreasing relation between p^H and q^H, starting at $\hat{q}^H = \bar{q}(t-1)$ and $\hat{p}^H = I^H - \frac{\beta}{(1-\beta)a_q}$ and reaching $\hat{p}^H = 0$ at the solution of

$$\frac{1-\beta}{\beta}\lambda I^H = \frac{\lambda}{a_q}\frac{\hat{q}^H}{\bar{q}(t-1)} + \frac{\hat{q}^H}{\bar{q}(t-1)} h'\left(\frac{\hat{q}^H}{\bar{q}(t-1)}\right) \; .$$

Hence, for every $\hat{q}^L$, (C.13), (C.14), and (C.16) have at most one solution for $\hat{p}^L$, $\hat{p}^H$, $\hat{q}^H$.

(2) Start with $\hat{q}^L = \bar{q}(t-1)$ and follow the procedure as described above. Plug the derived $\hat{q}^L, \hat{q}^H, \hat{p}^L, \hat{p}^H$ into (C.15).[66] If inequality (C.15) is satisfied, $\hat{q}^L, \hat{q}^H, \hat{p}^L, \hat{p}^H$ are the unique equilibrium values (case A).

(3) If inequality (C.15) is violated, add some small $\Delta > 0$ to $\hat{q}^L$ and repeat procedure (1). Keep adding $\Delta > 0$ to $\hat{q}^L$ until (C.15) is satisfied.[67] If the inequality is strict, apply a bisection algorithm until convergence to the equilibrium values (case B).[68]

(4) The unique symmetric solution to equations (C.13)-(C.17) may imply $q^L < q^H$. In such case there exists no separating equilibrium, and the unique equilibrium is a symmetric

[65] This solution may involve $q_i^H < q_i^L$ because the cost of innovation are made dependent on q_i^H in the above first-order-conditions, i.e. these conditions apply only if $q_i^H \geq q_i^L$. If $q_i^H < q_i^L$ they ignore the fact that the cost of innovation would be governed by q_i^L in such case.

[66] Note that by $I^H > \frac{1}{(1-\beta)a_q}$ there is indeed a solution for (C.13), (C.14), and (C.16) with $\hat{q}^L = \bar{q}(t-1)$.

[67] Note that by (C.13) increasing $\hat{q}^L$ results in a higher $\hat{p}^L$ and a lower $\hat{\theta}^L$. This does not affect (C.16), but shifts the solutions to (C.14) in the q^H, p^H diagram down and to the right, i.e. according to (C.14) every $\hat{q}^H$ is now associated with a lower $\hat{p}^H$. Together, this implies that the unique solution to (C.14) and (C.16) has now a higher $\hat{q}^H$ and a lower $\hat{p}^H$. Moreover, by (C.16), it is also associated with a higher $\hat{\theta}^H$. Now, a higher $\hat{q}^L$ in conjunction with a lower $\hat{\theta}^L$ and a higher $\hat{\theta}^H$ imply that the left hand side of (C.15) is decreasing.

[68] Note that this is indeed an equilibrium and in particular that the above reasoning also implies that no firm has an incentive to deviate by pooling types in its sector. This follows from the fact that given θ, i.e. given the equilibrium strategy of all other firms in the economy, the solution to equations (C.13) to (C.17) is uniquely optimal.

pooling equilibrium which is the solution to

$$\theta^L \left(v(q^P) - v(\bar{q}(t-1)) \right) + \frac{1}{a_q} = p^P \tag{C.18}$$

$$\theta^L v'(q^P) - \frac{1}{a_q A} - \frac{1}{\bar{q}(t-1)} h' \left(\frac{q^P}{\bar{q}(t-1)} \right) = 0 \; . \tag{C.19}$$

Using the definitions of θ and $v(\cdot)$, along with the fact that $A = \bar{q}(t-1)$ yields the expressions given in proposition $1'$ (case C).

(5) Finally, it remains to be shown that an equilibrium according to case (A) and (B), respectively, is unique if it exists. To see this, assume that a symmetric separating equilibrium exists with $\hat{q}^L < \hat{q}^H$ and note first that the arguments in steps (1) to (3) above imply that if an equilibrium according to case (A) and (B) exists, there can be no other separating equilibrium. To see that there can also be no pooling equilibrium in such case, suppose that there exists some $\tilde{q}^L$ such that equations (C.13), (C.14), and (C.16) are simultaneously satisfied if $\tilde{q}^H = \tilde{q}^L = \tilde{q}$ for all i. As by assumption there is a symmetric separating equilibrium with $\hat{q}^H > \hat{q}^L$, step (3) then implies that for these values the inequality in condition (C.15) must be strict. This, in combination with the fact that equation (C.16) holds implies that the left-hand-side of equation (C.19) would be negative for this value, i.e. in a potential pooling equilibrium it must be that $q < \tilde{q}$. But for $q^L < \tilde{q}$ we know from the reasoning above that the unique symmetric solution to equations (C.13), (C.14), and (C.16) implies $q^H > q^L$, i.e. there can be no pooling equilibrium.

□

C.4 Proof of proposition 2

We consider each case in proposition 2 in turn.

$\sigma \uparrow$ with $\frac{1}{a_q(1-\beta)} \geq 1$ $\frac{1}{a_q(1-\beta)} \geq 1$ implies that for $\sigma = 0$ we have $I^H \leq \frac{1}{a_q(1-\beta)}$. Hence, by proposition $1'$(i) there is zero growth in the economy up and until the point where $I^H = \frac{1}{a_q(1-\beta)}$, i.e. $\sigma = \left[\frac{1}{a_q(1-\beta)} - 1\right] \sqrt{\frac{\lambda}{1-\lambda}}$. As σ increases further, the economy starts growing, which follows from proposition $1'$(ii). Now, as σ and, hence, I^H increases, both (C.11) and (C.12) shift upwards. Note, however, that (C.12), which is downward sloping, shifts more, implying that g is monotonously increasing in σ.

$\sigma \uparrow$ with $\frac{1}{a_q(1-\beta)} < 1$ For $\sigma = 0$, the unique equilibrium is a pooling equilibrium with positive growth. As σ increases, and, hence, I^L decreases, the growth rate in the pooling equilibrium declines. To see this, observe that as I^L decreases, both equilibrium conditions for the pooling equilibrium shift downwards in the q^P, p^P diagram, but that (C.19) shifts more, implying that both q^P, and p^P decline. This, in turn, implies that higher-σ pooling equilibria are associated with a higher θ^H. Hence, for some σ large enough, (C.16) holds with equality.[69]

As we increase σ further, we switch from a pooling equilibrium to a separating equilibrium. In the separating equilibrium, an increase in σ has two different effects: (i) The associated increase in I^H has a strictly positive effect on growth.[70] (ii) The associated decrease in I^L has an indirect effect on growth as its effect on q^L and p^L impacts p^H and, hence, θ^H which, in turn, pins down q^H via (C.16). This effect may initially be negative but will eventually be positive as well for σ large enough such that θ^L and q^L sufficiently small.[71] We show numerically that for a broad range of parameter specifications the direct effect via an increase of I^H always dominates. In particular, we numerically solve for q^H as a function of σ assuming $h'(x) = c(x-1)^\alpha$ for all possible parameter specifications from

[69]Note that (C.16) and (C.19) together imply that (C.15) will also hold with equality and that for $q^H = q^L$ and therefore $p^H = p^L$ (C.14) trivially holds.

[70]To show (i), we proceed by contradiction. In particular, note that (C.16) defines an increasing relationship between θ^H and q^H, i.e. for growth to decline it must be that θ^H declines as well. (C.13) and (C.15) then imply that q^L must increase while θ^L decreases. But then equations (C.13) and (C.14) imply that p^H must decrease as well, a contradiction to θ^H being decreasing given that I^H increases and q^H decreases.

[71]A decrease in I^L has a negative (positive) effect on growth if for the previously given q^H the price p^H increases (decreases). A decrease in I^L will, ceteris paribus, lower θ^L and, hence, lower p^L at a given q^L to satisfy individual rationality of the low types. Firms do, however, respond to the decrease in I^L by lowering quality for the low types, q^L, according to optimality condition (C.15). Now, equations (C.13) and (C.14) define marginal changes in θ^L and q^L such that—given the new equilibrium values for q^L and p^L and the previous equilibrium values for q^H and p^H—incentive compatibility for high types is just satisfied. In particular, totally differentiating (C.13), we get

$$dp^L = d\theta^L \left[v(q^L) - v(\bar{q}(t-1))\right] + \theta^L v'(q^L) dq^L \ ,$$

while totally differentiating (C.13) and using that q^H, p^H, and θ^H are constant, we get

$$dp^L = \theta^H v'(q^L) dq^L \ .$$

Combining the previous two equations and rearranging terms, we get

$$\frac{dq^L}{d\theta^L} = \frac{v(q^L) - v(\bar{q}(t-1))}{(\theta^H - \theta^L)v'(q^L)} \ . \tag{C.20}$$

Equation (C.20) characterizes how q^L has to change in response to a marginal change in θ^L for (IR^L) and (IC^H) still to be satisfied given q^H, p^H, and θ^H. On the other hand, noting that in a separating equilibrium equation (C.15) holds with equality and totally differentiating using again that θ^H stays constant by assumption, we get

$$\frac{dq^L}{d\theta^L} = \frac{v'(q^L)}{v''(q^L)} \frac{1}{\lambda\theta^H - \theta^L} \ . \tag{C.21}$$

Equation (C.21) characterizes the optimal change of q^L in response to a marginal change of θ^L for a given θ^H. Now, if the right-hand-side of (C.21) is larger than the right-hand-side of (C.20), then the optimal response of q^L to a marginal decrease of θ^L is larger in absolute terms than the one needed to have (IC^H) satisfied at the old levels of q^H and p^H. As the high types value quality more, this decreases the attractiveness of contract (q^L, p^L) to high types which, in turn, allows firms to increase p^H. As a consequence, growth is lower via the negative general equilibrium effect of a higher p^H on θ^H. In other words, a decrease of I^L lowers growth if

$$\frac{v'(q^L)}{v''(q^L)} \frac{1}{\lambda\theta^H - \theta^L} > \frac{v(q^L) - v(\bar{q}(t-1))}{(\theta^H - \theta^L)v'(q^L)} \ .$$

the following set:

Table 8: Parameter choices for numerical solutions

λ :	$\{0.05, 0.15, ..., 0.95\}$
β :	$\{0.05, 0.15, ..., 0.95\}$
a_q :	$\{2, 4, ..., 20\}$
c :	$\{1, 2, 4, 8, 12\}$
α :	$\{0.05, 0.2, 1, 10, 20\}$

For each possible combination of these parameter specifications, q^H is increasing as a function of σ in a separating equilibrium.[72]

C.5 Proof of lemma 3

We show that constraint (IRf) cannot be binding for the low types. With $I^L \leq \hat{I}$ this is trivially the case. We thus consider the case of $I^L > \hat{I}$ and show that low types prefer quality $\bar{q}(t-1)$ over any imported quality.

As argued in the main body of the text, it is never optimal to import quality $q \leq \bar{q}(t-1)$. Hence, constraint (IRf) can only be binding if the preferred importing quality satisfies $q > \bar{q}(t-1)$. Combined with the fact that the marginal utility of quality is increasing in θ, this implies that low types will prefer quality $\bar{q}(t-1)$ over their best import option if this is the case for some $\hat{\theta} \geq \theta^L$.

Now, the income of low types is bounded from above by 1. Moreover, θ^L is decreasing in both, q^L and p^L. We conclude that θ^L is bounded from above by

$$\bar{\theta}^L := \frac{1 - \frac{1}{a_q}}{\beta \bar{q}(t-1)^{1-\beta}} \ .$$

A household of type $\bar{\theta}^L$ prefers quality $\bar{q}(t-1)$ over its best import option if

$$\bar{\theta}^L v(\bar{q}(t-1)) - \frac{1}{a_q} \geq \left[\bar{\theta}^L\right]^{\frac{1}{\beta}} \left[\bar{q}(t-1)\right]^{\frac{1-\beta}{\beta}} \chi(\tau) \ .$$

Using the definition of $v(\cdot)$ and rearranging terms, this is equivalent to

$$\frac{\theta^H - \theta^L}{\theta^L - \lambda\theta^H} < \frac{\beta}{1-\beta}\left[1 - \left(\frac{\bar{q}(t-1)}{q^L}\right)^{1-\beta}\right] \ .$$

Now, the right-hand-side of the above condition approaches zero as $q^L \to \bar{q}(t-1)$ while the left-hand-side is strictly positive, which shows that, indeed a decrease in I^L eventually has a positive effect on growth.

[72] If σ is large enough such that the economy reaches the point where innovating firms find it optimal to no longer serve the low types—i.e. if the solution to the system of equations in proposition $1'$(iii)(B) involves $q^L \leq \bar{q}(t-1)$—this is trivially the case and an increase in σ has a positive effect on growth as already noted above.

Using the definitions of $\bar{\theta}^L$, $v(\cdot)$, and $\chi(\tau)$, this can be rewritten as

$$\frac{1-\frac{1}{a_q}}{\beta\bar{q}(t-1)^{1-\beta}}\bar{q}(t-1)^{1-\beta} - \frac{1}{a_q} \geq \left[\frac{1-\frac{1}{a_q}}{\beta\bar{q}(t-1)^{1-\beta}}\right]^{\frac{1}{\beta}} [\bar{q}(t-1)]^{\frac{1-\beta}{\beta}} \left[\frac{a_q(1-\beta)}{\tau^2}\right]^{\frac{1-\beta}{\beta}} \beta \; .$$

Solving for τ and simplifying terms yields the expression given in Assumption 1.

□

C.6 Proof of proposition 4

To show the desired result, we consider the limiting case where domestic firms are just indifferent between innovating or not to serve the rich and then proceed by contradiction. In particular, we show that $q^{H,f} \leq q^H$ contradicts that it is optimal for domestic firms not to serve the rich households, where $q^{H,f}$ denotes the quality of the best import option and q^H denotes the optimal domestically-provided quality.

Suppose that $q^{H,f} \leq q^H$. The best importing quality satisfies the first-order condition for utility maximization of the rich

$$\theta^H v'(q^{H,f}) = \frac{\tau^2}{a_q A} \; ,$$

implying that

$$p^{H,f} = \frac{\tau^2}{a_q A} q^{H,f} = \theta^H v'(q^{H,f}) q^{H,f} \; , \tag{C.22}$$

where $p^{H,f}$ denotes the price of imported quality $q^{H,f}$. In the limiting case where domestic firms are just indifferent between serving or not the rich households, (IRf) is binding for the rich and, hence,

$$\theta^H v(q^{H,f}) - p^{H,f} = \theta^H v(q^H) - p^H$$

and therefore

$$\begin{aligned} p^H &= \theta^H \left[v(q^H) - v(q^{H,f}) + p^{H,f}\right] \\ &= \theta^H \int_{q^{H,f}}^{q^H} v'(x)dx + \theta^H v'(q^{H,f}) q^{H,f} \\ &\geq \theta^H v'(q^H) q^H \; . \end{aligned}$$

The second equality follows from using the fundamental theorem of calculus and equation (C.22). The inequality follows from the fact that $v(\cdot)$ is concave and that $q^{H,f} \leq q^H$, by assumption, and from simplifying terms. The above inequality is strict whenever $q^{H,f} < q^H$.

Now, there are two possibilities for when domestic firms are indifferent between serving or not the rich households. (i) Either they make zero profits and are equally well off stopping to innovate altogether. (ii) Or they would be equally well off innovating at a lower rate to just serve the poor. We show that neither is possible.

(i) The first order condition for q^H implies

$$\lambda \theta^H v'(q^H) - \lambda \frac{1}{a_q A} - \frac{1}{\bar{q}(t-1)} h'\left(\frac{q^H}{\bar{q}(t-1)}\right) = 0 \ . \tag{C.23}$$

Clearly, the fact that $p^H \geq \theta^H v'(q^H) q^H$ and the convexity of $h(\cdot)$ imply that firms are making strictly positive profits from just serving the rich households, i.e. a solution with no innovation cannot be optimal.

(ii) The fact that firms cannot be indifferent between serving both types of households or just the poor follows from a revealed preference argument. In particular, in the separating equilibrium, it must be that ($\mathrm{IR^L}$) is binding.[73] Moreover, firms could opt to offer poor households contract $(\tilde{q}^L, \tilde{p}^L)$, where we use this to denote the contract that firms would offer the low types in the hypothetical scenario where they just serve these types. This contract also satisfies ($\mathrm{IR^L}$) with equality, i.e. low types are indifferent between contracts $(\tilde{q}^L, \tilde{p}^L)$ and (q^L, p^L). We now show that offering $(\tilde{q}^L, \tilde{p}^L)$ and $(\tilde{q}^H, \tilde{p}^H)$ would yield strictly higher profits than when just offering $(\tilde{q}^L, \tilde{p}^L)$, where $\tilde{q}^H = q^H$ and $\tilde{p}^H$ is as defined below. In turn, this implies that the optimal contracts in the separating equilibrium yield strictly higher profits than when just offering $(\tilde{q}^L, \tilde{p}^L)$.

If $\tilde{q}^L \leq q^L$, this follows immediately because the change in the contract of the poor would not affect the contract for the rich and because firms make positive profits from serving the rich.

If $\tilde{q}^L > q^L$ and ($\mathrm{IC^H}$) is not binding, the same reasoning from before applies. If ($\mathrm{IC^H}$) is binding, then the price of q^H changes to

$$\tilde{p}^H = \tilde{p}^L + \int_{\tilde{q}^L}^{q^H} \theta^H v'(x) dx$$

[73] ($\mathrm{IRf^L}$) is never binding. Hence, the only possibility where ($\mathrm{IR^L}$) is not binding is a hypothetical case where ($\mathrm{IC^L}$) is binding, for otherwise firms could increase profits by increasing p^L which would only relax ($\mathrm{IC^H}$). ($\mathrm{IC^L}$), however, cannot be binding because, by assumption, the rich are indifferent between consuming the domestically produced quality q^H or importing a weakly lower quality. As richer households have a stronger taste for quality, poor households must then weakly prefer the best import choice of the rich households over (q^H, p^H) and, therefore, strictly prefer their own best import choice, i.e. ($\mathrm{IRf^L}$) would have to be strictly binding in such case, a contradiction.

and we have

$$
\begin{aligned}
&(1-\lambda)\left(\tilde{p}^L - \frac{1}{a_q A}\tilde{q}^L\right) - h\left(\frac{\tilde{q}^L}{\bar{q}(t-1)}\right) \\
&< \left(\tilde{p}^L - \frac{1}{a_q A}\tilde{q}^L\right) - h\left(\frac{\tilde{q}^L}{\bar{q}(t-1)}\right) \\
&< \left(\tilde{p}^L - \frac{1}{a_q A}\tilde{q}^L\right) - h\left(\frac{\tilde{q}^L}{\bar{q}(t-1)}\right) + \int_{\tilde{q}^L}^{q^H} \lambda\theta^H v'(x) - \lambda\frac{1}{a_q A} - \frac{1}{\bar{q}(t-1)}h'\left(\frac{x}{\bar{q}(t-1)}\right) dx \\
&= \left(\tilde{p}^L - \frac{1}{a_q A}\tilde{q}^L\right) + \lambda\left(\tilde{p}^H - \tilde{p}^L\right) - \lambda\frac{1}{a_q A}\left(q^H - \tilde{q}^L\right) - h\left(\frac{q^H}{\bar{q}(t-1)}\right) .
\end{aligned}
\tag{C.24}
$$

The first inequality follows from $\tilde{p}^L - \frac{1}{a_q A}\tilde{q}^L > 0$ and $\lambda > 0$. The second inequality follows from using (C.23) and the fact that $v(\cdot)$ is concave and $h(\cdot)$ is convex. The equality follows from solving the integral. The result then follows from noting that the expression in the last row is equal to total profits with this alternative separating contract.

□