TRADE AND PRODUCTIVITY: THE FAMILY CONNECTION REDUX

Klaus Prettner
Holger Strulik

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

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Klaus Prettner[*]

Holger Strulik[†]

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Abstract. We investigate the effects of demographic change and human capital accumulation on trade and productivity of domestic firms. In so doing we integrate a micro-founded education and fertility decision of households into a model of international trade with firm heterogeneity. Our framework leads to four testable implications: i) the export share of a country increases in the education level of its population, ii) the export share of a country decreases in the birth rate of its population, iii) the average profitability of firms increases in the education level of a country, iv) the average profitability of firms decreases in the birth rate of a country. We find that all four implications are supported by empirical evidence for a panel of OECD countries from 1960 to 2010. Our results suggest that investments in human capital accumulation, especially in higher education, are an important determinant of a country's international competitiveness. Furthermore, falling birth rates need not be a serious concern with respect to productivity and international competitiveness of countries.

JEL classification: F12, F14, I20, J11

Keywords: firm heterogeneity, international competitiveness, education, fertility decline

[*]University of Goettingen, Department of Economics, Platz der Goettinger Sieben 3, 37073 Goettingen, Germany; email: klaus.prettner@wiwi.uni-goettingen.de.

[†]University of Goettingen, Department of Economics, Platz der Goettinger Sieben 3, 37073 Goettingen, Germany; email: holger.strulik@wiwi.uni-goettingen.de.

1. Introduction

Over the last decades industrialized countries experienced tremendous demographical changes towards lower birth rates. While crude birth rates fell in all developed countries, the extent to which this happened differed considerably between them. For example, the U.S. had a crude birth rate of 24 children per 1000 inhabitants in 1950 and ended up with 14 children per 1000 inhabitants in 2010, Japan started with the same rate in 1950 but ended up with 9 children per 1000 inhabitants in 2010. European countries like France, Italy and the United Kingdom started from lower levels than Japan and the U.S. in 1950 and find themselves somewhere in between these two countries nowadays.

The immediate question that economists are confronted with is whether such tremendous changes will be a millstone around the neck of economic prosperity. This question has been analyzed extensively from different points of view. Some economists argue that support ratios have been declining and will decline even further such that fewer and fewer workers will be available for producing the goods and services that are consumed by all the individuals in an economy (see for example Gruescu, 2007; Bloom et al., 2010), others emphasize that the sustainability of social security and pension systems is threatened (see for example Gruber and Wise, 1998) and yet others analyze the changing savings behavior of individuals in the wake of changing demography (see for example Heijdra and Ligthart, 2006; Bloom et al., 2007; Krueger and Ludwig, 2007).

In this paper we focus on the effects of declining fertility on international competitiveness and productivity of domestic firms. To analyze this question we integrate into the state-of-the-art trade literature with firm heterogeneity (Melitz, 2003; Helpman et al., 2004) a micro-founded fertility and education decision at the household level. This allows us to investigate the impact of differences in fertility decisions and education investments on trade and productivity. Specifically, we show that declining fertility rates have beneficial effects on productivity and on international competitiveness of domestic firms because they are accompanied by higher schooling investments. The reason is a child quantity-quality substitution at the household level (Becker and Lewis, 1973; Galor, 2005). Higher schooling investments translate into higher individual labor productivity and thereby contemporaneously to a higher probability for entrepreneurs to establish a profitable firm.

These theoretical implications are helpful to explain the finding that for OECD countries in the

period 1960 – 2000 export share and output per firm are positively correlated with education and negatively negatively with population growth. Our results indicate that investments in human capital accumulation, especially in higher education, are an important determinant of a country's export share, that is, its international competitiveness. Furthermore, as far as international competitiveness is concerned, falling birth rates need not be as bad as it is often argued.

So far there exists relatively little research on the role of education in the new trade literature. Yeaple (2005) proposes a model in which homogeneous firms have access to a "high-tech technology" and a "low-tech technology". The work force is heterogeneous in their skill level and high skilled workers have a comparative advantage in high-tech production. In equilibrium, exporting firms are shown to be larger, to employ more high skilled labor, and to pay higher wages. A similar result has been derived by Manasse and Turrini (2001) for an economy in which firms are led by worker-entrepreneurs of different ability. The role of population size or growth is not investigated in these studies. Our study, by contrast, focuses on a homogeneous workforce and the impact of its human capital endowment on firm productivity through managerial education and human capital externalities at the firm level. In conjunction with a fertility–education trade-off at the household side it establishes a negative association between fertility (population growth) and firm productivity.

The association between international trade and the fertility and education behavior of households has been investigated as well by Galor and Mountford (2006, 2008). Employing a Ricardian argument for trade these studies argue in favor of a causal impact of trade on fertility and education. They consider a two-region model in which the North is endowed with a better industrial technology and specializes on industrial goods while the South specializes on agriculture. Because industrial production is relatively skill-intensive and agriculture is relatively labor intensive, trade increases the demand for education in the North and induces higher fertility in the South. Empirically, Galor and Mountford find that within OECD countries the volume of trade is positively associated with education and negatively associated with fertility while the opposite is found for non-OECD countries.

Acknowledging the important channel established by Galor and Mountford our paper explains the reverse causality running from the fertility and education decisions of households to aggregate productivity and the volume of trade. We focus on trade between similar countries populated by

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heterogeneous firms and differing in the education of their population and explain how choices at the household level lead to cross-country differences in aggregate productivity through the induced selection of firms into international trade. Galor and Mountford aptly coined the catchphrase "the family connection" for their studies on trade and productivity. The present paper resumes this line of research.

The paper proceeds as follows. Section 2 sets up a basic model that integrates a microfounded fertility and education decision into modern trade theory, based on firm heterogeneity. The model is simple enough to assess analytically the impact of falling birth rates and rising education on aggregate productivity and international competitiveness of domestic firms. The simple model, however, entails the drawback that changes in family behavior have to be conceptualized as triggered by exogenous parametric changes of the underlying model, in particular of the weight of children and education in the preferences of parents. An intellectually more appealing way to study the "family connection" is to rely on endogenous changes of family behavior and their feedback on firm productivity and income growth. In Section 3 we extend our theory in this respect and solve numerically for the long-run adjustment dynamics. Section 4 corroborates our findings with empirical evidence on the association of trade and productivity with education and population growth. Section 5 discusses implications and limitations of our study.

2. The model

2.1. **Households.** Consider a society populated by two overlapping generations, children and adults. Time is discrete and measured in terms of generations. We suppress time arguments whenever possible. Individual (household or firm) variables are denoted by lowercase letters, aggregate variables are denoted by capital letters. Adults experience utility from consuming an aggregate consumption good, from having a divisible number of children n and from providing their children with education e. Having a child incurs a minimum time cost ϕ (child rearing cost) and, following Galor and Weil (2000), a unit of child education requires an additional time cost e. Consequently, parents forgo wage income if they invest more in quantity or quality of children. It turned out that the algebra involved in the solution for the general equilibrium is more convenient when we measure all quantities in terms of units of human capital (efficiency units). Let therefore c and w denote consumption and wages per unit of human capital and let P denote to the aggregate price

level. A household's budget constraint is then given by

$$w\left(1 - \phi n - en\right) = Pc. \tag{1}$$

The left hand side of (1) represents lifetime income after taking into account child care in terms of quality and quantity investments, while the right hand side comprises consumption expenditures.

Suppose utility has the log-form such that

$$u = \log\left(c \cdot h\right) + \alpha \log\left(n\right) + \gamma \log\left(e\right), \tag{2}$$

in which h is human capital of the household, $c \cdot h$ is household consumption in units of goods and α and γ are the weights of child quantity and quality, respectively. Note that the household side of standard trade models is captured by the special case in which parents live indefinitely and do not have any children such that the human capital adjusted lifetime wage income of parents would be w. Maximizing (2) subject to (1) provides the household's demand for children and their education:

$$n = \frac{\alpha - \gamma}{\phi\left(1 + \alpha\right)}, \qquad e = \frac{\gamma\phi}{\alpha - \gamma}. \tag{3}$$

The implied time spent on working is given by $1 - (\phi + b)n = 1/(1 + \alpha)$. The quantity-qualitity trade-off can be easily established: If parents desire more children, they reduce education and vice versa (Becker and Lewis, 1973; Galor and Weil, 2000). Formally, the trade-off is obtained from (3) as $n = \gamma/(1 + \alpha) \cdot (1/e)$.

For simplicity we assume that education of a child is transformed one-to-one into human capital of an adult. This means that human capital of a member of the next generation is given by $h_{t+1} = e_t = \gamma\phi/(\alpha - \gamma)$. Let L_t denote the size of the adult generation of time t. Aggregate human capital of the next generation is then given by $H_{t+1} = n_t h_{t+1} L_t = \gamma L_t/(1 + \alpha)$. Notice that aggregate human capital of the next generation is increasing in the desire for education γ and decreasing in the desire for children α. This result is straightforwardly explained. A substitution of child quantity n by education e that keeps total child expenditure $e \cdot n$ constant sets free $\phi\Delta n$ units of parental time, which can be used to earn extra income. The additional income is partly spent on education such that overall education expenditure rises more strongly than child quantity falls. At

the macro side of the economy this trade-off means that human capital per person increases more strongly than the number of persons falls such that total available human capital increases.

Aggregate consumption consists of a homogeneous consumption good Z, which can be traded without costs, and of a continuum of costly tradeable CES consumption goods (as in Helpman et al., 2004). The sub-utility function of the representative individual with respect to consumption is iso-elastic in homogeneous good consumption and CES good consumption, that is, $c = Z^\eta Q^{1-\eta}$. This implies that households optimally spend a share η of their consumption budget on Z and a share $1 - \eta$ on Q. The CES part of the sub-utility function is given by

$$Q = \left[\int_{\omega \in \Omega} q(\omega)^\rho d\omega \right]^{1/\rho}. \tag{4}$$

In this expression the measure Ω denotes the mass of available goods, $q(\omega)$ denotes the quantity of each good ω, and the elasticity of substitution between the CES goods is $\sigma = 1/(1 - \rho) > 1$. Total expenditure on CES consumption goods is then given by

$$\frac{1 - \eta}{1 + \alpha} wL = \int_{\omega \in \Omega} p(\omega) q(\omega) d\omega \equiv R, \tag{5}$$

in which $p(\omega)$ is the price of variety ω, and R refers to the aggregate revenues of all firms that produce heterogeneous goods. The numerator on the left hand side of (5) adjusts for consumption of the homogeneous good and the denominator adjusts for the effect that parents with children do not supply their whole available time on the labor market and hence their lifetime wages are lower than w. Since all households are symmetric, their consumption allocation problem is solved by maximizing (4) subject to (5). This leads to the demand function $q(\omega) = (p(\omega)/P)^{-\sigma} Q$, with $P = \left[\int_{\omega \in \Omega} p(\omega)^{1-\sigma} d\omega \right]^{1/1-\sigma}$. Optimal expenditure for each variety ω can then be written as

$$r(\omega) = p(\omega) q(\omega) = R \left[\frac{p(\omega)}{P} \right]^{1-\sigma}, \tag{6}$$

where we note that $R = PQ$.

2.2. **Firms.** Human capital is the only factor of production. The homogeneous consumption good is produced with a constant input coefficient, which is normalized to unity, implying a unit wage in efficiency units (per unit of human capital). Costless trade of the homogeneous good ensures factor price equalization at the human capital adjusted wage rate; $w = 1$ for all countries. Note that

the notation in efficiency units implies that better educated workers receive higher labor income and that firms pay higher wages in countries populated by a better educated workforce. The modeling of the production sector for CES goods follows the literature of international trade with firm heterogeneity (Eaton and Kortum, 2001, 2002; Bernard et al., 2003; Melitz, 2003; Helpman 2004; with the last two being especially relevant in our context).

There exists a continuum of firms, each producing a variety ω. Each firm has therefore access to a production technology $q(\omega) = A(\omega) \cdot [\tilde{h}(\omega) - f]$. Fixed costs f are the same for all firms, while productivity of human capital $A(\omega)$ differs between them. Human capital demand $\tilde{h}(\omega)$ is given by $\tilde{h}(\omega) = f + q(\omega)/A(\omega)$. The intuition is that if firms want to produce a desired quantity $q(\omega)$ given the firm-specific productivity $A(\omega)$, they first have to incur the fixed costs of production in terms of human capital, f, and then they have to employ $q(\omega)/A(\omega)$ units of human capital to be able to fulfill their manufacturing schedule.

Profits are given by revenues of sales net of the wage bill, $\pi = p(q) \cdot q - w\left[(q/A) + f\right]$. Maximizing profit, taking the demand function of households into account, leads to the optimal pricing rule $p(A) = w/(\rho A)$. The optimal price is a markup $1/\rho$ over marginal costs $1/A$.

Using the demand function $q(\omega)$, the expression for profits can be reformulated as $\pi = (r(\omega)/\sigma) - f$, in which $r(\omega) = R\left[p(\omega)/P\right]^{1-\sigma}$ are firm-specific revenues and r/σ denotes operating profits. Inserting $p(\omega) = 1/(\rho A)$ into r provides an expression of firm revenues as a function of macroeconomic aggregates and firm specific productivity:

$$ r = R \left(\frac{1}{\rho A P} \right)^{1-\sigma} = R(\rho A P)^{\sigma-1}, \tag{7} $$

such that profits become $\pi = (R/\sigma)(\rho A P)^{\sigma-1} - f$. Using $q(\omega) = (p(\omega)/P)^{-\sigma} Q$, the following ratios between the size and revenue of two firms indexed by 1 and 2 can be calculated

$$ \frac{q(A_1)}{q(A_2)} = \left(\frac{A_1}{A_2} \right)^{\sigma}, \qquad \frac{r(A_1)}{r(A_2)} = \left(\frac{A_1}{A_2} \right)^{\sigma-1} \tag{8} $$

implying that relative firm size in terms of the produced quantity as well as relative revenue crucially depend on firm specific productivity, replicating a central result of Melitz (2003).

2.3. **Aggregation over firms.** For the sake of tractability and in line with the theoretical and empirical literature (Axtell, 2001; Helpman et al., 2004; Chaney, 2008; Eaton et al., 2011), we

assume that firm productivity is derived from a Pareto distribution $G(A) = 1 - (A_m/A)^a$, where minimum productivity A_m is equal to one. In deviation from the earlier literature, however, we postulate that the shape parameter a is decreasing in the human capital endowment per person, capturing the phenomenon that in an economy where people are better educated, it is easier for an entrepreneur to establish a productive enterprise.

There exist at least two complementing channels through which education of the workforce exerts a positive effect on firm productivity. The first channel acknowledges positive external effects of human capital in (team) production, which are observationally equivalent to an increase in productivity (Lucas, 1988; Battu et al., 2003; Munch and Skaksen, 2008). The second channel takes into account that the education of entrepreneurs has a positive impact on firm productivity, i.e. that better educated entrepreneurs are more likely to draw a favorable firm productivity. Empirically there exists supporting evidence for both channels. Firms of high productivity are on average run by better educated managers and employ a better educated work force (Grossmann, 2007; La Porta and Shleifer, 2008; Bloom and Van Reenen, 2007, 2010; Syverson, 2011; and, in particular, Gennaioli et al., 2013).

A parsimonious and analytically convenient way to represent the positive effect of human capital on firm productivity is to set $a = 1/h$. Since $1/h = (\alpha - \gamma)/(\gamma\phi)$, the cumulative Pareto distribution function then reads

$$G(A) = 1 - \left(\frac{1}{A}\right)^{\frac{\alpha - \gamma}{\gamma\phi}}$$

and has positive support over $[1, \infty)$. This treatment formalizes the notion that the probability to draw a high productivity firm is not completely exogenous – as in Melitz (2003) – but influenced positively by the level of education in society. As explained above, this is so because of external knowledge spillovers between employers or because higher education increases the probability to draw a capable manager of the firm.

The density function of firm productivity $g(A)$ is given by

$$g(A) = G'(A) = \frac{\alpha - \gamma}{\gamma\phi} A^{-\left(1 + \frac{\alpha - \gamma}{\gamma\phi}\right)}. \tag{9}$$

The existence of the expected value of A relies on the parameter restriction $(\alpha - \gamma)/\gamma\phi > 1$, a sufficient condition for which is $n \geq 1$, implying that population growth is non-negative. Expected

productivity is then determined as $E(A) = \int_1^\infty A g(A) dA = (\alpha - \gamma)/(\alpha - \gamma - \gamma\phi)$. Inspecting the derivatives

$$\frac{\partial E(A)}{\partial \alpha} = -\frac{\gamma\phi}{(\alpha - \gamma - \gamma\phi)^2} < 0, \qquad \frac{\partial E(A)}{\partial \gamma} = \frac{\alpha\phi}{(\alpha - \gamma - \gamma\phi)^2} > 0,$$

we conclude that expected firm productivity is higher in an economy where people prefer to have fewer children and/or prefer to educate their children better.

2.4. **Firm entry and exit.** Firms are initially identical and face a fixed investment cost to enter the market, expressed in units of human capital and denoted by f_e. After entering, firms draw a productivity level A. Firms drawing a low A that would not allow their operating profits to cover their fixed costs choose to exit immediately. The other firms start to produce and henceforth face a constant probability δ of a bad shock in every period that would force them to exit. In equilibrium, on which we focus from now on, entry is equal to exit. The value function of a firm — assuming that there is no discounting of the future on top of the risk of exit — is

$$v(A) = \max\left(0, \sum_{t=0}^\infty (1-\delta)^t \pi(A)\right) = \max\left(0, \frac{\pi(A)}{\delta}\right).$$

Analogous to Melitz (2003) we define a cut-off level of productivity as $A^* = \inf(A : v(A) > 0)$. Firms with lower productivity, that is, firms facing $A < A^*$, exit immediately and do not produce. At the cut-off level of productivity, firms do not make any profits such that $\pi(A^*) = 0$. Together with the density function of the Pareto distribution, the probability of successful entry, $1 - G(A^*)$, determines the distribution of productivity conditional on entry denoted by $\mu(A)$ as

$$\mu(A) = \begin{cases} \frac{g(A)}{1-G(A^*)} & \text{if } A > A^*, \\ 0 & \text{otherwise,} \end{cases}$$

where

$$\frac{g(A)}{1 - G(A^*)} = \frac{\alpha - \gamma}{\gamma\phi} A^{*\frac{\alpha-\gamma}{\gamma\phi}} (A)^{-\left(1 + \frac{\alpha-\gamma}{\gamma\phi}\right)}.$$

Consequently, productivity A is a function of the cut-off productivity for successful entry, A^*. Defining average productivity as $\widetilde{A} = \left[\int_{A^*}^\infty A^{\sigma-1} \mu(A) dA\right]^{\frac{1}{\sigma-1}}$, we arrive at

$$\widetilde{A} = \left[\frac{\alpha - \gamma}{(1-\sigma)\gamma\phi + \alpha - \gamma}\right]^{\frac{1}{\sigma-1}} A^*, \tag{10}$$

which is a linear function of the cut-off productivity level. Non-negative average productivity requires $(1-\sigma)\gamma\phi + \alpha - \gamma > 0$, implying $(\alpha - \gamma)/(\gamma\phi) > \sigma - 1 > 0$, where the latter inequality ensures that average productivity is finite. It holds because $\sigma > 1$.

We define average revenues by $\bar{r} = r(\tilde{A})$ and average profits by $\bar{\pi} = \pi(\tilde{A}) = \bar{r}/\sigma - f$ and note that a firm does not make profits at the cut-off level of productivity such that $\pi(A^*) = r(A^*)/\sigma - f = 0 \Rightarrow r(A^*) = \sigma f$. Using $\bar{r} = r(A^*)\left[\tilde{A}(A^*)/A^*\right]^{\sigma-1} = r(A^*)(\alpha - \gamma)/\left[(1-\sigma)\gamma\phi + \alpha - \gamma\right]$, average profits at the cut-off are given by

$$\bar{\pi} = f \cdot \left[\frac{\alpha - \gamma}{(1-\sigma)\gamma\phi + \alpha - \gamma} - 1\right] \equiv f \cdot \kappa. \tag{11}$$

Melitz (2003) refers to this expression as the zero cut-off profit condition. In our case, where productivity levels are drawn from a Pareto distribution, the term in square brackets is independent of A^* and given by the compound constant κ.

The present value of average profit flows, $\bar{v}$, is determined by the probability of a bad shock driving the firms under consideration out of business: $\bar{v} = \bar{\pi}/\delta = \int_{A^*}^{\infty} v(A)\mu(A)dA$. Since the probability of successful entry is $1 - G(A^*)$ and the expected value of entry net of fixed costs has to be zero, we can solve for average profits as

$$\bar{\pi} = \delta f_e \left(A^*\right)^{\frac{\alpha - \gamma}{\gamma\phi}}. \tag{12}$$

Equations (11) and (12) can be solved for average profits and the cut-off level of productivity:

$$\bar{\pi} = \frac{f\gamma(\sigma - 1)\phi}{\alpha - \gamma - \gamma(\sigma - 1)\phi}, \tag{13}$$

$$A^* = \exp\left\{\frac{\gamma\left[\ln(\delta) - \ln\left(\frac{f\gamma(\sigma-1)\phi}{\alpha - \gamma - \gamma(\sigma-1)\phi}\right) + \ln(f_e)\right]}{(\gamma - \alpha)\phi}\right\}. \tag{14}$$

This leads to the following proposition.

Proposition 1. *In a closed economy, an increase in the desire for fertility decreases average productivity and average profits whereas an increase in the desire for education increases average productivity and average profits.*

Proof. The derivatives of $\overline{\pi}$ with respect to α and γ are, respectively,

$$\frac{\partial \overline{\pi}}{\partial \alpha} = -\frac{f\gamma(\sigma - 1)\phi}{[\alpha - \gamma - \gamma(\sigma - 1)\phi]^2} < 0, \qquad \frac{\partial \overline{\pi}}{\partial \gamma} = \frac{f\alpha(\sigma - 1)\phi}{[\alpha - \gamma - \gamma(\sigma - 1)\phi]^2} > 0,$$

meaning that average profits decrease in the desire for fertility and increase in the desire for education. Furthermore, recall that Equation (12) implies that $(\overline{\pi}/\delta f_e)^{\frac{\gamma\phi}{\alpha - \gamma}} = A^*$. Since $\alpha - \gamma > 0$, the base and the exponent of this expression are both increasing in γ and decreasing in α. Consequently, the cut-off productivity also decreases in the desire for fertility and increases in the desire for education. This establishes that A^* is an increasing function of γ and a decreasing function of η.

Furthermore, when using equation (10), we can show that average productivity increases in γ and decreases in η for given A^*, which establishes the proof.

$$\frac{\partial \widetilde{A}}{\partial \alpha} = -\frac{A^*\alpha\phi\{[\alpha - \gamma]/[(1 - \sigma)\gamma\phi + \alpha - \gamma]\}^{\frac{1}{\sigma - 1} - 1}}{[\gamma - \alpha + \gamma(1 - \sigma)\phi]^2} < 0,$$

$$\frac{\partial \widetilde{A}}{\partial \gamma} = \frac{A^*\alpha\phi\{[\alpha - \gamma]/[(1 - \sigma)\gamma\phi + \alpha - \gamma]\}^{\frac{1}{\sigma - 1} - 1}}{[\gamma - \alpha + \gamma(1 - \sigma)\phi]^2} > 0.$$

□

To summarize, productivity is higher in an economy in which parents prefer to have fewer and better educated children.

2.5. **Open Economy.** Similar to Melitz (2003) the transition to trade does not affect individual firm level variables but the decision of firms to enter the home and foreign markets. Assume that there are $m + 1$ countries and iceberg transport costs apply for the CES consumption good such that $\tau > 1$ units have to be shipped in order for one unit to arrive at the destination (Samuelson, 1952; Krugman, 1980; Baldwin et al., 2003). Furthermore, there are fixed costs for exploring the export market and for adjusting the product to foreign standards. These are denoted by $f_{ex} > 0$ and measured in terms of human capital. The domestic price charged by a firm is $p_d(A) = 1/(\rho A)$ and the corresponding export price is $p_x(A) = \tau p_d(A) = \tau/(\rho A)$. The revenues from domestic sales are $r_d(A) = R(P\rho A)^{\sigma - 1}$. Following Helpman et al. (2004) in assuming that countries do not differ too much in size such that all countries face the same wages, demand, and cut-off levels, the

corresponding revenues from export sales amount to

$$r_x(A) = R \left(\frac{P\rho A}{\tau} \right)^{\sigma-1} = \tau^{1-\sigma} r_d(A). \qquad (15)$$

Revenue of a firm depends on export status and is given by

$$r(A) = \begin{cases} r_d(A) & \text{no export,} \\ r_d(A) + r_x(A) = \left(1 + m\tau^{1-\sigma}\right) r_d(A) & \text{export.} \end{cases}$$

Following Melitz (2003), we assume that the export fixed cost f_{ex} is paid every period, which is tantamount to paying a discounted stream of these costs ($f_x = f_{ex}/\delta$) only once at the beginning of the export business. The profits of domestic sales and of foreign sales are then, respectively,

$$\pi_d = \frac{r_d(A)}{\sigma} - f, \qquad \pi_x = \frac{r_x(A)}{\sigma} - f_x, \qquad (16)$$

and total profits amount to $\pi(A) = \pi_d(A) + max\left[0, \ \pi_x(A)\right]$. The domestic and export cut-off levels of productivity are given by $A^* = \inf\left[A : v(A) > 0\right]$ and $A_x^* = \inf\left[A : A \geq A^* \text{ and } \pi_x(A) > 0\right]$, respectively, where it is apparent that $A_x^* \geq A^*$. The cut-off levels of productivity can be determined via the conditions $\pi_d(A^*) = 0$ and $\pi_x(A_x^*) = 0$. There the central assumption is that $\tau^{\sigma-1} f_x > f \ \Rightarrow \ A_x^* > A^*$. This means that export costs are sufficiently large such that the following partitioning of firms occurs (Melitz, 2003; Helpman, 2006):

- $A < A^*$: firms exit,
- $A^* < A \leq A_x$: firms produce for the home market only,
- $A > A_x^*$: firms produce for home and export markets.

The probability of exporting conditional on successful entry is a unique function of A^*:

$$\Phi_x = \frac{1 - G(A_x^*)}{1 - G(A^*)} = \left[\frac{A^*}{A_x^*}\right]^{\frac{\alpha-\gamma}{\gamma\phi}}. \qquad (17)$$

Define $\tilde{A}_x$ as the average productivity of exporting firms and let $\tilde{A}$ be an index of average productivity of all firms competing in a country (domestic and foreign). Then average revenues consist of revenues due to domestic sales and revenues due to foreign sales $\bar{r} = r_d(\tilde{A}) + \Phi_x r_x(\tilde{A})$ and average profits amount to $\bar{\pi} = \pi_d[\tilde{A}(A^*)] + \Phi_x \pi_x[\tilde{A}(A_x^*)]$. The cut-off productivity condition for firms requiring indifference between exporting and non-exporting is $\pi_x(A_x^*) = 0 \Leftrightarrow \pi_x(\tilde{A}_x) = f_x \kappa$.

Using equations (8), (15) and (16) we get

$$A_x^* = \left(\frac{f_x}{f}\right)^{\frac{1}{\sigma-1}} \tau A^* \tag{18}$$

such that A_x^* is a linear function of A^*. From the zero cut-off profit conditions of domestic producers and of exporters we get average profits as

$$\bar{\pi} = \pi_d(\tilde{A}) + \Phi_x \pi_x(\tilde{A}_x) = f\kappa + \Phi_x m f_x \kappa. \tag{19}$$

Again we have that the expected net present value of a successful firm must be zero due to free entry, that is, $v_e = [1 - G(A^*)]\bar{\pi}/\delta - f_e \overset{!}{=} 0$, which is the case for $\bar{\pi} = \frac{\delta f_e}{1-G(A^*)}$. Consequently, the free entry condition remains unchanged as compared to the closed economy case. Regardless of the profit differences across firms due to the export status, the expected value of future profits in equilibrium must be equal to fixed investment costs. The two equations (18) and (19) determine $\bar{\pi}$ and A_x^*. Once A^* is known from the closed economy solution, we get A_x^*, $\tilde{A}$, $\tilde{A}_x$, $1 - G(A^*)$ and Φ_x. Recalling that $\kappa = (\alpha - \gamma)/[(1 - \sigma)\gamma\phi + \alpha - \gamma - 1]$ in case of our particular Pareto distribution we arrive at

$$A_x^* = B\tau e^{\frac{C}{(\gamma-\alpha)\phi}}, \tag{20}$$

$$\bar{\pi} = \left[\frac{(\sigma-1)\gamma\phi}{(1-\sigma)\gamma\phi + \alpha - \gamma}\right]\left[f + m f_x\left(\frac{1}{B\tau}\right)^{\frac{\alpha-\gamma}{\gamma\phi}}\right] \tag{21}$$

with $B \equiv (f_x/f)^{\frac{1}{\sigma-1}}$ and

$$C \equiv \gamma\left[\ln(\delta) - \ln\left(\frac{f\gamma(\sigma-1)\phi}{\alpha - \gamma - \gamma(\sigma-1)\phi}\right) + \ln(f_e)\right].$$

At this stage we can state the two central results of our paper.

Proposition 2. *For the open economy, an increase in the desire for fertility α decreases average productivity and average profits, while an increase in the desire for education γ increases average productivity and average profits.*

Proof. It can be shown that, as in autarky, $\partial\bar{\pi}/\partial\alpha < 0$ and $\partial\bar{\pi}/\partial\gamma > 0$. From equations (14), (20), the expression $(\bar{\pi}/\delta f_e)^{\frac{\gamma\phi}{\alpha-\gamma}} = A^*$, and the fact that in this expression the base and the exponent both decrease in α and increase in γ due to $\alpha - \gamma > 0$ it follows that the export cut-off productivity

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increases in the desire for education and decreases in the desire for having many children. Together with Lemma **??** this establishes that the same holds true for average productivity in an economy. □

Let international competitiveness be defined by the probability of a firm to export (Φ_x). We then observe the following result.

Proposition 3. *An increase in the desire for fertility decreases international competitiveness, while an increase in the desire for education increases international competitiveness.*

Proof. Substituting for A_x^* in the probability of exporting conditional on successful entry yields

$$\Phi_x = \left[\left(\frac{f_x}{f} \right)^{\frac{1}{\sigma-1}} \tau \right]^{\frac{\gamma\phi}{\alpha-\gamma}}. \tag{22}$$

The derivative of this expression with respect to α is negative, whereas the derivative with respect to γ is positive. □

Recalling from Proposition 2 that firms are larger in terms of profits in economies where parents prefer fewer and better educated children we conclude from Proposition 3 that, ceteris paribus, the export share of GDP is increasing in education and declining in fertility.

In order to prepare for the empirical analysis of, naturally, heterogeneous countries, we now give up the symmetry assumption and allow for differing home and foreign demand levels. Following Helpman et al. (2004) we denote by R_x and P_x revenues and prices in the rest of the world as being obtained by appropriate aggregation over all foreign countries. This means that export revenues of a domestic firm are given by

$$r_x(A) = R_x \left(\frac{P_x \rho A}{\tau} \right)^{\sigma-1} = \tau^{1-\sigma} \frac{R_x}{R} \left(\frac{P_x}{P} \right)^{\sigma-1} r_d(A). \tag{23}$$

Following the same steps of analysis as before we obtain

$$A_x^* = D\tau e^{\frac{C}{(\gamma-\alpha)\phi}}, \tag{24}$$

$$\bar{\pi} = \left[\frac{(\sigma-1)\gamma\phi}{(1-\sigma)\gamma\phi + \alpha - \gamma} \right] \left[f + f_x \left(\frac{1}{D\tau} \right)^{\frac{\alpha-\gamma}{\gamma\phi}} \right] \tag{25}$$

with $D \equiv (f_x R_x / f R)^{\frac{1}{\sigma-1}} P_x / P$ and C given as before. Aggregate revenues at home, R, decline in response to an increase in α and do not respond to changes in γ, an effect that reinforces the pre-

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viously obtained results. However, the response of the domestic price level (and consequently also the response of A_x^* and $\bar{\pi}$) with respect to variation of α and γ becomes, in general, indeterminate. If the price level increases very strongly in response to increasing α or decreases very strongly in response to increasing γ, it could in principle be possible that the previously outlined mechanism is reversed. This means that empirical analysis is useful to decide whether the following hypotheses derived from the symmetric model are corroborated by the data: i) countries with a better educated population should be more successful in exporting, ii) countries with a higher fertility rate should be less successful in exporting, iii) firms in countries with a better educated population should be more profitable, iv) firms in countries with a higher fertility rate should be less profitable.

3. Long-Run Demographic Change and International Competitiveness

The basic model relies on parametric changes in the desire for children and education in order to motivate the connection between fertility, education, and competitiveness. This is analytically convenient but may appear to be intellectually not fully convincing. It seems to be more desirable to elicit "the family connection" as an outcome of endogenous demographic and behavioral change based on stable preferences. In this section we extend the basic model in this direction. This allows, in the spirit of unified growth theory (Galor, 2005), for an explanation of observable cross-country differences as outcome of a differentiated take-off to modern growth. Contemporaneous countries displaying high fertility and low investments in education are conceptualized as being at an early stage of the demographic transition, whereas countries displaying low fertility and high education have already reached a later stage of the transition. Ceteris paribus, we will not only observe that forerunners of the demographic transition produce higher income per capita than latecomers – as in e.g. in Galor and Weil (2000) – but also that forerunners are populated by on average more productive firms – as observed by e.g. Gollin, 2008 – and that firms of forerunners are more likely to export.

In principle there are numerous possibilities to generate transitional dynamics of a demographic–economic model (see Galor, 2005 for an overview). Here we follow a "minimal-intensive" approach by mildly extending the basic model with informal education ($\bar{e}$), which could be thought of as skills acquired by children through observation of their parents and peers at work. Let e_t continue to denote costly formal acquired education. In contrast to the basic model we assume that formal

education is costly in terms of income rather than in terms of parental time such that the budget constraint reads $wh_t(1-\phi n_t) = Pc_t h_t + e_t$. The expenditure share of education per child is assumed to translate one-to-one into human capital per member of the next adult generation. Taking into account the normalization $w = 1$, the modified utility function and the modified equation of motion for human capital read:

$$u = \log(c_t h_t) + \alpha \log(n_t) + \gamma \log(e_t + \bar{e}) \tag{26}$$

$$h_{t+1} = \frac{e_t}{h_t} + \bar{e}. \tag{27}$$

Henceforth we focus on problems that exhibit an interior solution for optimal education and fertility. The interior solution is given by

$$e_t = \frac{h_t \gamma \phi - \bar{e}\alpha}{\alpha - \gamma}, \qquad n_t = \frac{(\alpha - \gamma)h_t}{(1 + \alpha)(h_t \phi - \bar{e})}. \tag{28}$$

The interior solution preserves the quantity-quality trade-off from the simple model. Declining fertility is observed along with increasing education,

$$n = \frac{(h_t \gamma \phi - \bar{e}\alpha)h_t}{(h_t \phi - \bar{e})(1 + \gamma)} \cdot \frac{1}{e_t}.$$

Additionally, human capital of the parent h_t is now negatively associated with fertility and it is positively associated with the education of children. Notice that for $\bar{e} = 0$, or for $h_t \to \infty$, the solution for n_t and h_{t+1} coincides with the solution of the simple model. Using again a/h_t, the cumulative Pareto distribution $G(A)$ modifies to

$$G(A_{t+1}) = 1 - \left(\frac{1}{A_{t+1}}\right)^{\frac{\alpha-\gamma}{\xi(\gamma\phi-\alpha\bar{e}/h_t)+(\alpha-\gamma)\bar{e}}}.$$

We see that a growing level of human capital gradually increases the probability for an entrepreneur to draw a high productivity.

We continue with the analysis analogous to the Section 2. The detailed calculations are summarized in the Appendix. Unfortunately the model can no longer be assessed analytically. The resulting system of equations that we solve numerically is given by equations (A.11) to (A.15). For the benchmark run of the model we set parameter values and initial endowment as summarized in Table 1. After solving the model we convert generations into years assuming that a generation

takes 25 years. We set the initial time t_0 to 1750.

TABLE 1. Parameter values for the numerical example

Parameter	Value	Parameter	Value
f	1	f_e	1.5
f_x	2	σ	1.5
$\bar{e}$	0.05	α	0.5
γ	0.4	ϕ	0.25
τ	1.2	δ	0.1
m	190	h_0	0.38

FIGURE 1. Evolution of Human Capital and International Competitiveness
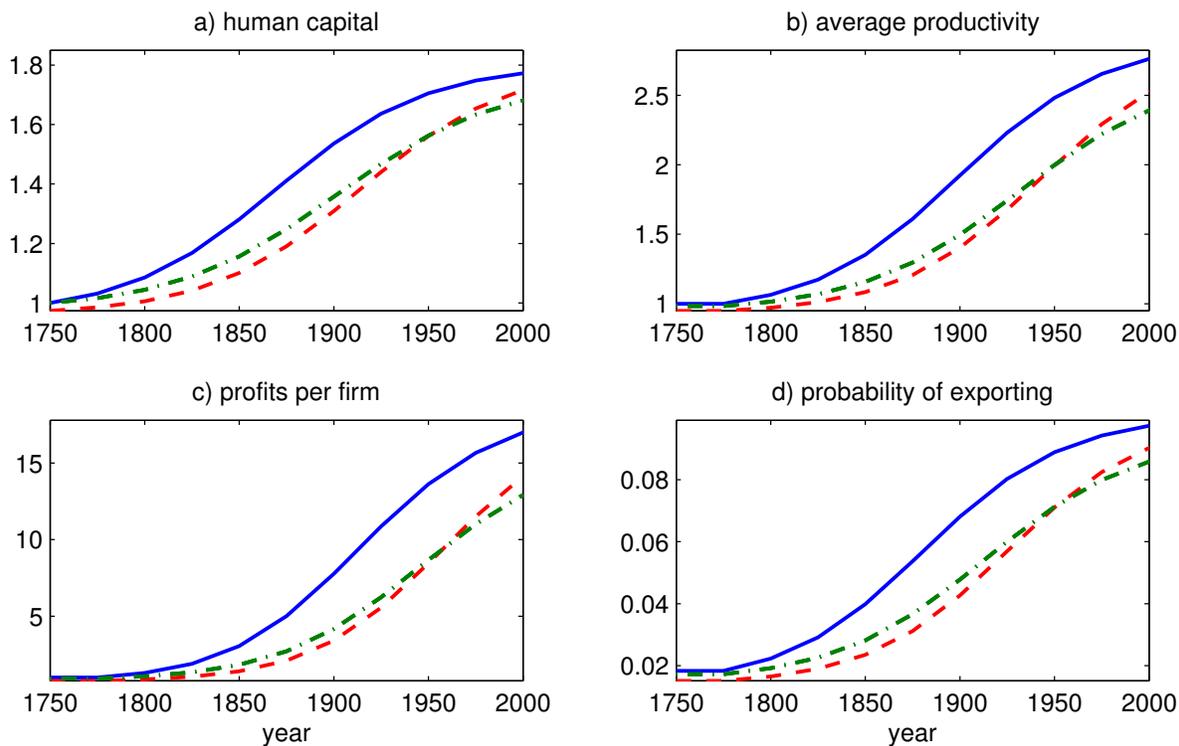
Solution trajectories of the extended model for 3 different specifications of countries. Solid lines: $h(0) = 0.38$; dashed lines: $h(0) = 0.37$; dash-dotted lines: $h(0) = 0.38$ and $\gamma = 0.399$. All other parameters values as specified in Table 1.

The results of our numerical example are displayed in Figure 1 where we see the evolution for central variables over a time span of 250 years: human capital in panel (a), average productivity in panel (b), profits per firm in panel (c), and the probability of exporting conditional on entry

in panel (d). We have normalized the trajectories (a)-(c) by dividing through their respective initial values. Results for the benchmark specification are reflected by solid lines. Human capital is predicted to increase by factor 1.8 from 1750 to 2000. Using a Mincer equation $h_t = \exp(\theta s_t)$ the predicted increase corresponds with an increase from 3 to 12 years of schooling when the return on schooling θ is 0.07; a prediction that is roughly in line with the historical schooling trends observed for the Western countries (Baier et al., 2006).

Altogether the dynamic behavior of the economy is consistent with the comparative static behavior obtained for the basic economy of Section 2. This means that the association between the level of human capital and fertility on the one hand and firm's profits and average productivity on the other hand are preserved: In economies richer in human capital the fertility rate is lower and average profits per firm and average productivity are higher.

Notice that there are now two ways to explain cross-country differences in education, firm productivity, and international competitiveness. Countries may share the same fundamentals but differ in their initial endowments and thus in the timing of the take-off to growth or they may differ in their fundamentals. This is demonstrated in Figure 1 by comparing the benchmark economy with two alternative economies. One economy shares all the fundamentals and starts with lower endowment of human capital (dashed lines). The other economy shares the same initial conditions but puts less weight on education (dash-dotted lines). Asymptotically human capital, productivity, and international competitiveness of economies sharing the same fundamentals will converge (solid and dashed lines) while both economies outperform the fundamentally different economy (solid and dashed vs. dash-dotted lines). In any case, irrespective of the cause of contemporaneous cross-country differences in human capital, productivity and competitiveness are higher in the country that displays higher human capital and lower fertility rates.[1]

4. Empirical Analysis

The analysis in Sections 2 and 3 have elaborated why the export share and the profitability of firms are negatively associated with birth rates and and positively with the level of education. A first glance at the validity of these implications across countries is provided by Figure 2. The four

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[1]Notice that – as a side effect – the model captures also the stylized fact that the number of firms in an economy declines with economic development. The mechanism is based on imperfect competition, international specialization, and firm productivity enhanced by education. It complements existing explanations based on factor supply and norm enforcement (Lucas, 1978; Gollin, 2008; Lindner and Strulik, 2011).

panels of the figure show the evolution of export share and average productivity as measured by GDP per worker together with the evolution of birth rates and tertiary education for a population-weighted OECD average. We see that export share and firm productivity increase with declining fertility declines and rising education. This pattern is consistent with Propositions 2 and 3 and the dynamic behavior investigated in Section 3.

FIGURE 2. Education, Fertility, and Competitiveness Trends in the OECD
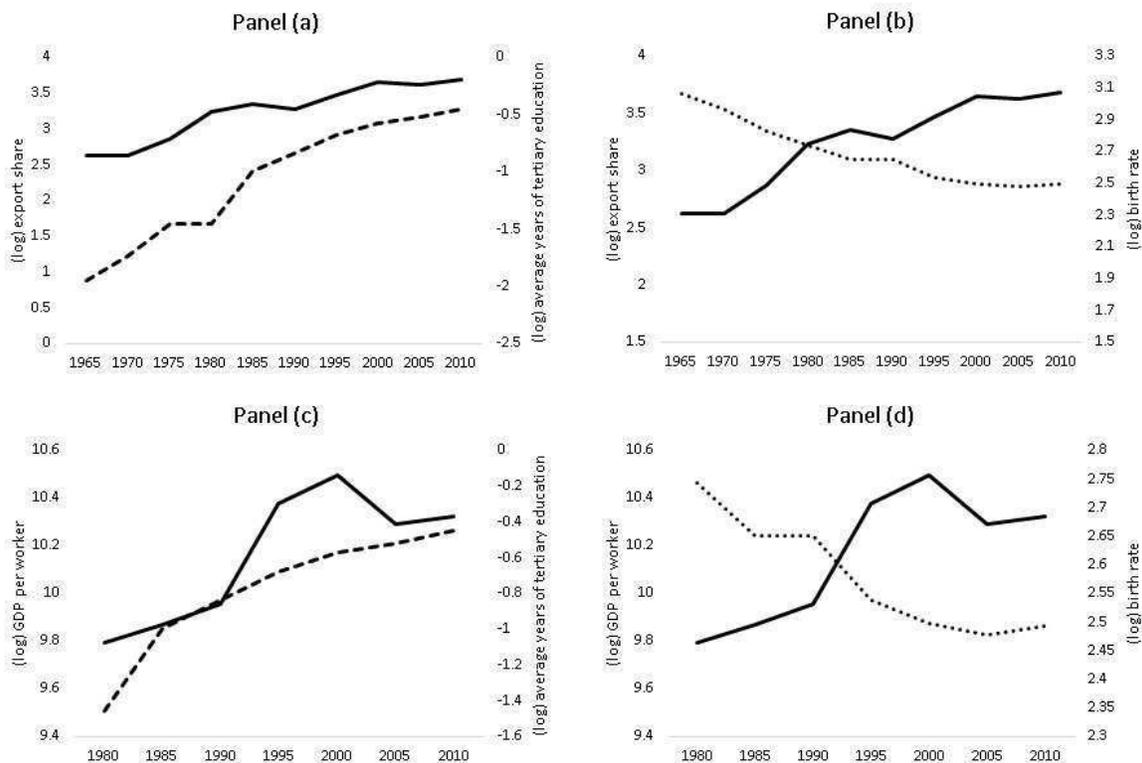
The series represent population-weighted averages of OECD countries. Panel (a) shows the evolution of the export share of GDP (left axis, solid line) and average years of tertiary education (right axis, dashed line). Panel (b) shows the evolution of the export share (left axis, solid line) and the birth rate (in children per 1000 inhabitants; right axis, dotted line). Panel (c) shows the evolution of GDP per worker (left axis, solid line) and average years of tertiary education (right axis, dashed line). Panel (d) shows the evolution of GDP per worker (left axis, solid line) and the birth rate (right axis, dotted line). All variables are expressed in logs.

In order to analyze these patterns carefully we constructed a panel data-set for all OECD countries from 1960 to 2010 evaluated in five year steps using the World Development Indicators, Penn World Tables of Heston et al. (2011) and the Education Statistics and the Enterprise Survey of the World Bank (2011). The data-set comprises export shares, GDP per worker and GDP per firm as

productivity measures, birth rates as indicators for demographic developments, and mean years of tertiary education of the population above the age of 15 as an indicator for human capital. The focus on tertiary education is motivated by the notion that the productivity of firms is most heavily influenced by the presence of well educated managers, scientists, and engineers.

We use population size and per capita GDP to control for country size and income differences, and the investment shares of GDP to control for differences in capital intensity. Due to the panel structure of our data set we are able to control for country-specific effects that remain constant over time, like geographical and cultural characteristics, as well as for time varying effects that impact upon all countries in a similar vein, like changes in technology, in particular, transport technology[2].

Figure 3 shows the scatterplots of the logarithm of a country's export share against the logarithm of its birth rate (left picture) and the logarithm of its average years of tertiary education (right picture). The simple correlation indicates support of predictions i) and ii), that is, there appears to be a negative relationship between fertility and the international competitiveness of an economy as well as a positive relationship between higher education and competitiveness.

FIGURE 3. Education, Fertility, and Exports: 1960 – 2010
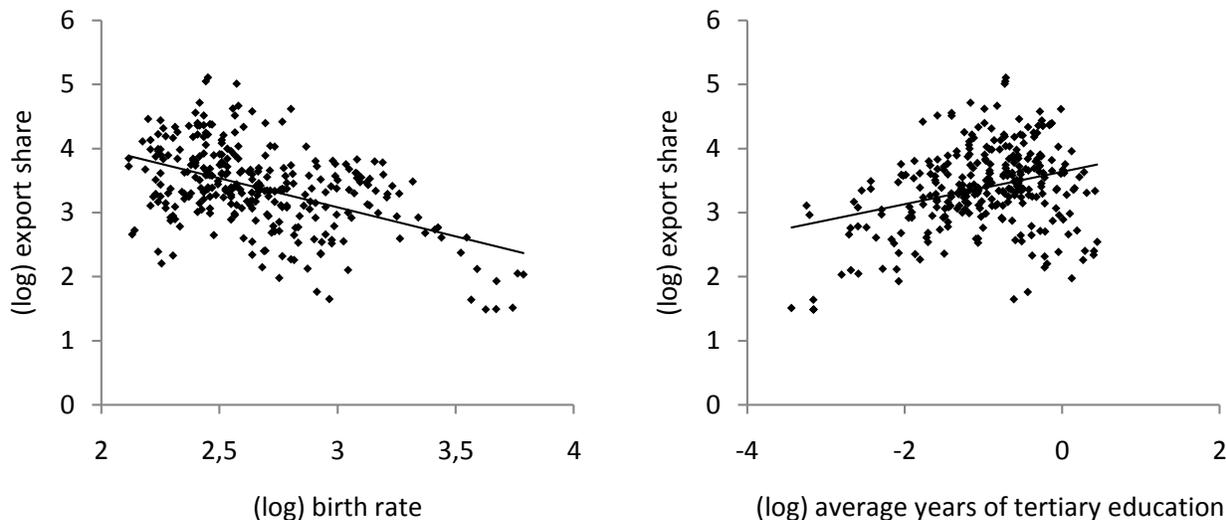
Left: correlation between the logarithm of the export share (in percent) and the logarithm of the birth rate (in children per 1000 inhabitants); Right: correlation between the logarithm of the export share and the logarithm of average years of tertiary education; The sample contains OECD countries from 1960 to 2010 in 5 year steps.

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[2]The most important geographical predictors of trade are distance to trading partners and whether a country is landlocked. Note that we analyze OECD countries between which barriers to technology adoption and diffusion are presumably less severe than between developed and developing countries.

FIGURE 4. Education, Fertility, and Output per Worker: 1960 − 2010
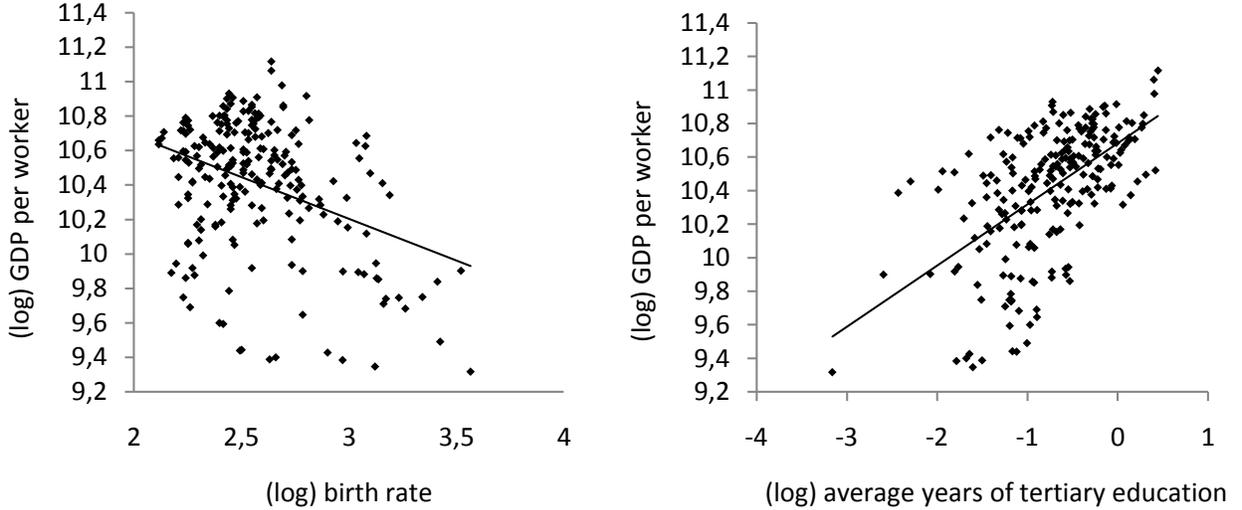
Left: correlation between the logarithm of GDP per worker and the logarithm of the birth rate (in children per 1000 inhabitants); Right: correlation between the logarithm of GDP per worker and the logarithm of average years of tertiary education. Sample as for Figure 3.

Ideally we would like to test the theory using data for GDP per firm as an indicator of firm profitability. But we do not have data for this variable prior to the year 2000, a drawback that reduces the size of our sample considerably. We thus use also GDP per worker as an alternative proxy for firm profitability. This approach seems to be justified by the observation of a high correlation between GDP per firm and GDP per worker — a simple regression provides an adjusted R^2 of more than 0.6 and a highly significant positive coefficient estimate. Figure 4 shows the scatterplots of the logarithm of a country's GDP per worker against the logarithm of the birth rate (left picture) and the logarithm of average years of tertiary education (right picture). The simple correlation in this case indicates support of predictions iii) and iv), that is, there appears to be a negative relationship between fertility and GDP per worker as well as a positive relationship between higher education and GDP per worker.

To examine the validity of our theoretical implications in more detail, we estimated specifications of the form

$$Export_{i,t} \;=\; \beta_j treat_{i,t-1,j} + \beta_k cont_{i,t-1,k} + \epsilon_i + \psi_t + u_{i,t}, \tag{29}$$

$$pfGDP_{i,t} \;=\; \beta_j treat_{i,t-1,j} + \beta_k cont_{i,t-1,k} + \epsilon_i + \psi_t + u_{i,t}, \tag{30}$$

$$pwGDP_{i,t} \quad = \quad \beta_j treat_{i,t-1,j} + \beta_k cont_{i,t-1,k} + \epsilon_i + \psi_t + u_{i,t}, \tag{31}$$

where the dependent variable is either the logarithm of the export share ($Export$), the logarithm of GDP per firm ($pfGDP$), or the logarithm of GDP per worker ($pwGDP$) in country i at time t, $treat_{i,t-1,j}$ refers to the treatment variables j of country i at time $t-1$, these are, the logarithm of the birth rate ($birth$) and the logarithm of mean years of tertiary education of the population above the age of 15 ($ayts$). Finally, $cont_{i,t-1,k}$ refers to the control variables k for country i at time $t-1$, these are, the logarithm of per capita GDP ($pcGDP$), the logarithm of the investment share ($invest$), and the logarithm of the population size ($popsize$). In an attempt to reduce endogeneity issues the variables on the right hand side are lagged by one period (five years). The coefficient estimates we are interested in are the β_j's, while the coefficient estimates for β_k refer to the marginal effects of the control variables. Each equation contains country fixed effects, ϵ_i, and time fixed effects, ψ_t, while the error term is denoted by $u_{i,t}$ and assumed to have mean zero and a diagonal variance-covariance matrix.

Table 2 contains the results of the regressions specified in equations (29)-(31). The positive association between the export share and average years of tertiary education is significant at the 5% level, as is the negative association between the export share and the birth rate. If we use GDP per firm as dependent variable we estimate a positive association with average years of tertiary education as well as a negative association with birth rates but both coefficients are not statistically significant. These results are not surprising considering the small sample of 93 observations available for the estimation of 46 coefficients. When we use alternatively GDP per worker we have 223 observations for our estimation. The positive association between productivity per worker and average years of tertiary education is then significant at the 10% level, while the negative association between productivity per worker and the birth rate is significant at the 1% level. Altogether these results give credence to Propositions 2 and 3 and the four predictions i)-iv).

As a robustness check we used firm level data for a sample of developing countries collected by Gennaioli et al. (2013) and analyzed whether education of managers has a positive association with firm size, productivity and success in exporting. Table 3 contains the results, where the dependent variables are the export share, the logarithm of value added, and the logarithm of employment, each belonging to firm i in region j. We control for the inverse distance of a firm to the coast ($invdist$),

TABLE 2. Estimation results for the regressions specified in equations (29)-(31)

	Dependent Variable (in logs)					
	export share	export share	GDP per firm	GDP per firm	GDP per worker	GDP per worker
$ayts$	0.198		0.012		0.134	
	(0.073)**		(0.189)		(0.068)*	
$birth$		-0.332		-0.066		-0.375
		(0.141)**		(0.22)		(0.129)***
$popsize$	0.492	0.463	0.739	0.771	-0.322	-0.343
	(0.297)	(0.311)	(0.961)	(0.83)	(0.249)	(0.249)
$pcGDP$	-0.279	-0.253				
	(0.166)	(0.157)				
$invest$	0.267	0.240	0.018	0.019	0.107	0.125
	(0.105)**	(0.100)**	(0.287)	(0.07)	(0.083)	(0.091)
R^2	0.68	0.67	0.26	0.26	0.77	0.79
OBS	289	289	93	93	223	223
country fe	yes	yes	yes	yes	yes	yes
time fe	yes	yes	yes	yes	yes	yes

Regressors are lagged by one time period. Standard errors are reported below the coefficient estimates in parentheses. One asterisk indicates significance at the 10% level, two asterisks indicate significance at the 5% level and three asterisks indicate significance at the 1% level. R^2 denotes the fraction of within variation explained by the corresponding model, and OBS stands for the number of observations.

population size ($popsize$), whether a firm is owned by foreigners (fgn_own), and geographical influences by means of the temperature ($temp$). The treatment variable is years of schooling of the manager of a firm. We see that it is positively associated with all three dependent variables at the 1% significance level. This result further substantiates the claim that education is an important explanatory variable with regards to international competitiveness and productivity.

5. CONCLUSIONS

In this paper we analyzed the implications of demographic change for productivity and international competitiveness of domestic firms by augmenting a state-of-the-art international trade model with an explicit fertility and education decision of households. In light of the ongoing debate on losing competitiveness due to demographic change (World Economic Forum, 2011), our results indicate that some of the fears may be exaggerated. Taking the quantity-quality trade-off into

Table 3. Firm Exports, Productivity and Manager Education

	Dependent Variable		
	export share	(log) value added	(log) employment
$education of manager$	2.153	0.269	0.138
	(0.548)***	(0.044)***	(0.027)***
$invdistcoast$	71.295	-7.421	1.937
	(19.172)***	(3.974)*	(0.669)***
$popsize$	9.745	-1.225	0.355
	(2.735)***	(0.471)**	(0.113)***
fgn_own	0.229	0.016	0.007
	(0.044)***	(0.003)***	(0.001)***
$temp$	-1.459	0.278	-0.137
	(1.034)	(0.200)	(0.027)***
R^2	0.20	0.19	0.30
OBS	6,312	6,314	6,314

Firm level data from Gennaioli et al. (2013). Standard errors in parentheses. One asterisk indicates significance at the 10% level, two asterisks indicate significance at the 5% level and three asterisks indicate significance at the 1% level.

account our theory suggests that countries with lower fertility will also have a better educated work force. This in turn fosters individual and firm productivity, which increases the likelihood that a firm is internationally competitive. As a consequence, such a firm will be more successful in export markets. Empirical evidence for the OECD countries over the time span 1960 to 2010 supports the theoretical findings by indicating a positive association between the export share of a country and the average years of tertiary education of its population, as well as by indicating a negative association between the export share of a country and its birth rate.

The focus of our analysis has been on one particular channel by which demographic change influences productivity and competitiveness, namely, on the child quantity-quality trade-off. This does, of course, not mean that we deny other important and potentially unfavorable implications of demographic change, which have already been analyzed extensively in the literature like, for example, the pressures on social security and retirement systems or the increase of the dependency ratio. Here we wanted to stress that there is also a bright side of demographic change. For that purpose we focused on productivity and competitiveness and made no claims regarding welfare. As shown in the Appendix, welfare effects resulting from fertility change are indeed ambiguous.

This is so because the well-known market size effect (Krugman, 1980; Melitz, 2003) operates in the opposite direction and may outweigh the positive effects of increasing firm productivity.

In a related study (Strulik et al., 2012) we integrated the child quantity-quality trade-off into an R&D-based growth model and obtained a similarly optimistic outlook for a future of declining birth rates. There, the driving factor was the human capital allocated for R&D and the associated knowledge spillovers in this activity. Combining this approach with the theory presented in the present paper is a challenging task for future research, which may help to further identify the determinants of firm productivity in modern trade theory.

Acknowledgements

5.1. **Aggregate Revenues and Profits.** Aggregate revenues and aggregate profits can be written as, respectively,

$$
\begin{aligned}
R &= \int_0^\infty r(A)M\mu(A)dA = \int_0^\infty r(\widetilde{A})\left(\frac{r(A)}{r(\widetilde{A})}\right)M\mu(A)dA \\
&= r(\widetilde{A})M, \tag{A.1}
\end{aligned}
$$

$$
\Pi = \int_0^\infty \pi(A)M\mu(A)dA = M\left(\frac{r(\widetilde{A})}{\sigma} - f\right), \tag{A.2}
$$

by using $r(A)/r(\widetilde{A}) = \left(A/\widetilde{A}\right)^{\sigma-1}$ and $\int_0^\infty A^{\sigma-1}\mu(A)dA = \widetilde{A}^{\sigma-1}$. In equilibrium the number of entrants (denoted with a subscript e) is equal to the number of exiting firms such that

$$
[1 - G(A^*)]M_e = \delta M \tag{A.3}
$$

$$
\left(\frac{1}{A^*}\right)^{\frac{\alpha-\gamma}{\gamma\psi}} M_e = \delta M, \tag{A.4}
$$

where M_e denotes the mass of entrants. Labor market clearing requires

$$
L - L_z = L_p + L_e,
$$

where L_z is the labor cost of production of the homogeneous good, L_p is the labor cost of CES production and L_e the labor cost of entry into CES production. Note that the same allocation between sectors holds for human capital because it is embodied and individual human capital does not depend on the sector in which a worker supplies her skills. The aggregate wage bill in the CES sector must be equal to revenue minus profits

$$
L_p = R - \pi \tag{A.5}
$$

and the following holds for the labor cost of entry

$$
L_e = M_e f_e = \frac{\delta M}{1 - G(A^*)} f_e = M\pi = \Pi. \tag{A.6}
$$

Thus, for aggregate revenues we have

$$
R = L_p + \Pi = L_p + L_e = \frac{1 - \eta}{1 + \alpha} L \tag{A.7}
$$

where $1 - \eta$ corrects for the budget (and the labor) allocated to the production of the homogeneous good.

5.2. **Aggregate Price Index.** Denoting the probability of successful entry by $\mu(A)$, the price index $P = \left[\int_{\omega\in\Omega} p(\omega)^{1-\sigma}d\omega\right]^{1/1-\sigma}$ can be rewritten as

$$
P = \left[\int_0^\infty \left[\frac{1}{\rho A}\right]^{1-\sigma} M\mu(A)dA\right]^{\frac{1}{1-\sigma}} = \frac{M^{\frac{1}{1-\sigma}}}{\rho\widetilde{A}}
$$

with
$$\widetilde{A} = \left[\int_0^\infty A^{\sigma-1}\mu(A)dA\right]^{\frac{1}{\sigma-1}}$$
being a weighted geometric mean of productivities and therefore tantamount to average productivity. The price index becomes $P = M^{\frac{1}{1-\sigma}}p(\widetilde{A})$ after applying $p(A) = 1/(\rho A)$.

5.3. Aggregate Output. Aggregate output can be written as

$$Q = \left[\int_0^\infty q(A)^\rho M\mu(A)dA\right]^{\frac{1}{\rho}} = M^{\frac{1}{\rho}}\left[\int_0^\infty q(\widetilde{A})^\rho \left(\frac{q(A)}{q(\widetilde{A})}\right)^\rho \mu(A)dA\right]^{\frac{1}{\rho}} = M^{\frac{1}{\rho}}q(\widetilde{A})$$

after making use of $\left[\int_0^\infty A^{\sigma-1}\mu(A)dA\right]^{\frac{\sigma}{\sigma-1}} = \tilde{A}^\sigma$.

5.4. The Mass of Producing Firms and the Price Index in Equilibrium. The mass of producing firms in equilibrium (normalized by individual human capital) follows from $\overline{\pi} = \overline{r}/\sigma - f$ as

$$M = \frac{R}{\overline{r}} = \frac{(1-\eta)L}{(1+\alpha)(\overline{\pi}+f)\sigma} = \frac{[\alpha - \gamma - \gamma(\sigma-1)\psi](1-\eta)L}{(1+\alpha)(\alpha-\gamma)\sigma f}.$$

Multiplying both sides by individual human capital, updating for one time period and using $H_{t+1} = h_{t+1}b_t L_t = \gamma/(1+\alpha)L_t$ we can rewrite the equilibrium mass of producing firms in the next period (non-normalized) as

$$h_{t+1}M_{t+1} = \frac{[\alpha - \gamma - \gamma(\sigma-1)\psi](1-\eta)\gamma L_t}{(\alpha-\gamma)(1+\alpha)^2\sigma f}.$$

The derivatives of this expression with respect to the desire of parents for the number of children and their education are, respectively,

$$\frac{\partial h_{t+1}M_{t+1}}{\partial\alpha} = \frac{\gamma(\eta-1)\left[2(\alpha-\gamma)^2 + \gamma(2\gamma-3\alpha-1)(\sigma-1)\psi\right]L_t}{\sigma f(1+\alpha)^3(\alpha-\gamma)^2\sigma},$$

$$\frac{\partial h_{t+1}M_{t+1}}{\partial\gamma} = -\frac{(\eta-1)\left[2(\alpha-\gamma)^2 + \gamma(\gamma-2\alpha)(\sigma-1)\psi\right]L_t}{\sigma f(1+\alpha)^2(\alpha-\gamma)^2\sigma}.$$

Both of these expressions have an ambiguous sign.

The (non-normalized) price index for CES goods in equilibrium is equal to

$$P_{t+1} = \frac{(h_{t+1}M_{t+1})^{\frac{1}{1-\sigma}}}{\rho\widetilde{A}}.$$

Note that all firm-level variables $(A^*, \widetilde{A}, \overline{\pi}, \overline{r})$ do not depend on scale L, while M changes proportionally with L. Therefore the response of next period's price level and next period's aggregate welfare to changes in the desire for fertility and education is ambiguous as well. It can be shown that these results carry over to the case of an open economy.

5.5. Calculations for the Extended Model. For the extended model the cumulative Pareto distribution $G(A)$ and the associated density function $g(A)$ are obtained as

$$G(A_{t+1}) = 1 - \left(\frac{1}{A_{t+1}}\right)^{\frac{\alpha-\gamma}{\xi(\gamma\phi-\overline{e}\alpha/h_t)+(\alpha-\gamma)\overline{e}}},$$

$$g(A_{t+1}) = G'(A_{t+1}) = \frac{\alpha - \gamma}{\xi(\gamma\phi - \bar{e}\alpha/h_t) + (\alpha - \gamma)\bar{e}} A_{t+1}^{-\left(1 + \frac{\alpha - \gamma}{\xi(\gamma\phi - \bar{e}\alpha/h_t) + (\alpha - \gamma)\bar{e}}\right)}.$$

The expected productivity level that a firm draws at time $t + 1$ is

$$E(A_{t+1}) = \int_1^\infty A_{t+1} g(A_{t+1}) dA_{t+1} = \frac{\alpha - \gamma}{\alpha - \gamma - \xi(\gamma\phi - \bar{e}\alpha/h_t) - (\alpha - \gamma)\bar{e}}.$$

It increases in human capital of generation t. The reason is that parents with higher wages and higher human capital are more likely to invest in education of their offspring, implying that the mean of the Pareto distribution shifts outward.

The distribution of productivity conditional on entry is

$$\mu(A_{t+1}) = \frac{g(A_{t+1})}{1 - G(A_{t+1}^*)} =$$

$$= \frac{\alpha - \gamma}{\xi(\gamma\phi - \bar{e}\alpha/h_t) + (\alpha - \gamma)\bar{e}} \left(A_{t+1}^*\right)^{\frac{\alpha - \gamma}{\xi(\gamma\phi - \bar{e}\alpha/h_t) + (\alpha - \gamma)\bar{e}}} A_{t+1}^{-\left(1 + \frac{\alpha - \gamma}{\xi(\gamma\phi - \bar{e}\alpha/h_t) + (\alpha - \gamma)\bar{e}}\right)},$$

and the probability of exporting conditional on entry is

$$\Phi_{x,t+1} = \frac{1 - G(A_x^*)}{1 - G(A^*)} = \left[\frac{A^*}{A_x^*}\right]^{\frac{\alpha - \gamma}{\xi(\gamma\phi - \bar{e}\alpha/h_t) + (\alpha - \gamma)\bar{e}}}.$$

Defining average productivity as $\widetilde{A}_{t+1} = \left[\int_{A_{t+1}^*}^\infty A_{t+1}^{\sigma-1} \mu(A_{t+1}) dA_{t+1}\right]^{\frac{1}{\sigma-1}}$ provides:

$$\widetilde{A}_{t+1} = \left\{\frac{\alpha - \gamma}{(1 - \sigma)\left[\xi(\gamma\phi - \bar{e}\alpha/h_t) + (\alpha - \gamma)\bar{e}\right] + \alpha - \gamma}\right\}^{\frac{1}{\sigma-1}} A_{t+1}^*. \tag{A.8}$$

Following the steps of the analysis for the basic model we obtain for the closed economy

$$\pi_{t+1} = \frac{f(\sigma - 1)(h_t(\gamma\xi\phi + \bar{e}(\alpha - \gamma)) - \alpha\bar{e}\xi)}{\alpha\bar{e}\xi(\sigma - 1) + h_t(-\gamma + \alpha(\bar{e}(-\sigma) + \bar{e} + 1) + \gamma(\sigma - 1)(\bar{e} - \xi\phi))} \tag{A.9}$$

$$A_{t+1}^* = \left\{\frac{f(\sigma - 1)(h_t(\gamma\xi\phi + \bar{e}(\alpha - \gamma)) - \alpha\bar{e}\xi)}{\delta f_e\left[\alpha\bar{e}\xi(\sigma - 1) + h_t(-\gamma + \alpha(\bar{e}(-\sigma) + \bar{e} + 1) + \gamma(\sigma - 1)(\bar{e} - \xi\phi))\right]}\right\}^{\frac{\gamma\xi\phi}{\alpha - \gamma} - \frac{\alpha\bar{e}\xi}{(\alpha - \gamma)h_t} + \bar{e}}.$$
$$\tag{A.10}$$

For the derivation of the dynamic system of the open economy first note that human capital evolves according to

$$h_{t+1} = \frac{\xi(\gamma\phi - \bar{e}\alpha/h_t) + (\alpha - \gamma)\bar{e}}{\alpha - \gamma}. \tag{A.11}$$

By making use of equations (18) and (19), we can derive the following expressions from the solutions (A.9) and (A.10) of the closed economy

$$\pi_{t+1} = \frac{(\sigma - 1)(\alpha\bar{e}\xi - h_t(\gamma\xi\phi + \bar{e}(\alpha - \gamma)))\left\{mf_x\left[\frac{\left(\frac{f_x}{f}\right)^{\frac{1}{1-\sigma}}}{\tau}\right]^{\frac{(\alpha - \gamma)h_t}{h_t(\gamma\xi\phi + \alpha\bar{e} - \gamma\bar{e}) - \alpha\bar{e}\xi}} + f\right\}}{h_t(\gamma\xi(\sigma - 1)\phi + (\alpha - \gamma)(\bar{e}(\sigma - 1) - 1)) - \alpha\bar{e}\xi(\sigma - 1)}, \tag{A.12}$$

$$A^*_{x,t+1} = \tau \left(\frac{f_x}{f} \right)^{\frac{1}{\sigma-1}} \times$$

$$\left\{ \frac{f(\sigma-1)\left(h_t(\gamma\xi\phi + \bar{e}(\alpha-\gamma)) - \alpha\bar{e}\xi\right)}{\delta f_e\left(\alpha\bar{e}\xi(\sigma-1) + h_t(-\gamma + \alpha(\bar{e}(-\sigma) + \bar{e} + 1) + \gamma(\sigma-1)(\bar{e}-\xi\phi))\right)} \right\}^{\frac{\gamma\xi\phi}{\alpha-\gamma} - \frac{\alpha\bar{e}\xi}{(\alpha-\gamma)h_t} + \bar{e}} .$$

$$\tag{A.13}$$

These expressions refer to the evolution of profits per firm and cut-off productivity in the open economy. Using the equations (A.8) and (18), we can then calculate average productivity in the open economy as

$$\tilde{A}_{t+1} = \frac{A^*_{x,t+1}}{\tau} \left\{ \frac{f}{f_x} \frac{\alpha-\gamma}{(1-\sigma)\left[\xi(\gamma\phi - \bar{e}\alpha/h_t) + (\alpha-\gamma)\bar{e}\right] + \alpha - \gamma} \right\}^{\frac{1}{\sigma-1}} . \tag{A.14}$$

Finally, the probability of exporting conditional on entry follows immediately from equation (17) as

$$\Phi_{x,t+1} = \left[\frac{\left(\frac{f_x}{f} \right)^{\frac{1}{1-\sigma}}}{\tau} \right]^{\frac{\alpha-\gamma}{\xi(\gamma\phi - \bar{e}\alpha/h_t) + (\alpha-\gamma)\bar{e}}} . \tag{A.15}$$

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