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# EXPORTING, WAGE PROFILES, AND HUMAN CAPITAL: EVIDENCE FROM BRAZIL

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## ABSTRACT

Export activity shapes workers' experience-wage profiles. Using employer-employee and customs data for Brazilian manufacturing, we document that workers' experience wage profiles are steeper at exporters than at non-exporters and, among exporters, steeper at exporters shipping to high-income destinations. We develop and quantify a model featuring worker-firm wage bargaining, export-market entry by multi-worker firms, and human capital accumulation by workers to interpret the data. Human capital growth can explain one-half of the differences in wage profiles between exporters and non-exporters. We show that increased human capital per worker can account for one-half of the overall gains in real income from trade openness.

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An online appendix is available at http://www.nber.org/data-appendix/w34580

# I Introduction

Differences in life-cycle wage growth between firms are well documented (Herkenhoff et al., 2018; Gregory, 2021; Jarosch, Oberfield and Rossi-Hansberg, 2021), and so are differences in wages between exporters and non-exporters (Bernard and Jensen, 1995). Yet little is known about the effects of firms' export activity on workers' life-cycle wage dynamics. Exporters are more productive than non-exporters. This differential is partly driven by self-selection of more capable firms into export activity (e.g., Clerides, Lach and Tybout, 1998), but there can also be productivity improvements after exporting. For example, Atkin, Khandelwal and Osman (2017) find that exporting improves firms' technical efficiency in a randomized experiment, and De Loecker (2007) shows that firms' productivity gains may increase when firms export to high-income countries. In addition to changing firm-level outcomes, exporting may impact workers.

We study empirically the relationship between a firm's export-market participation and its workers' wage profiles. We rely on Brazilian employer-employee data and customs records between 1994–2010 in the manufacturing sector, assembling a long-run panel with detailed information on job characteristics. To construct experience-wage profiles, we measure workers' potential experience in the labor market as years elapsed after schooling and then estimate how one extra year of experience within a job (worker-firm match) affects wage growth for workers at different life cycle stages. In principle, both one more year of experience and a change in aggregate time effects can lead to a wage change. To resolve this well-known collinearity problem (Deaton, 1997), we draw upon the widely used Heckman–Lochner–Taber approach (Heckman, Lochner and Taber 1998, henceforth HLT, also applied in, e.g., Huggett, Ventura and Yaron 2011; Lagakos et al. 2018). The centerpiece of this approach is to assume that there are no experience returns at the end of the working life, so that wage growth among old workers allows us to isolate time effects.

We document three facts. First, after staying in a job for 20 years from the beginning of the career, a typical worker's wage growth is 85% at non-exporters and 104% at exporters, indicating a sizeable difference of 19 percentage points in life-cycle wage growth between exporters and non-

exporters. Second, firm productivity proxies and firm fixed effects explain most of the differences in experience-wage profiles between exporters and non-exporters, hinting that exporters essentially provide higher returns to experience. Third, after controlling for productivity proxies, workforce composition, and firm fixed effects, returns to experience are higher when firms export to high-income destinations. We find that the increase in returns to experience materializes immediately following a firm's entry into a high-income destination, and this result is robust when we apply a propensity-score matching approach or exploit a substantive currency devaluation to address the endogeneity concern of export decisions.

We show that our empirical results are robust to using a subsample of workers who are observed in the data from young age on and for whom we can construct experience based on the observed work history. Because of possible breaks in the observed employment records (for reasons such as unemployment), which resolve the collinearity between experience and time, we do not need to impose the HLT assumption in estimation for this subsample. We still find that previous experience at exporters (especially at those selling to high-income markets) is more valuable than experience at non-exporters, and that these experience gains are largely portable when workers switch firms. The estimated experience effects are of a similar magnitude to our previous findings. We also show similar results for workers displaced under a sudden closure of large firms. These displaced workers' returns to previous experience are more likely to be shaped by learning than seniority (Jacobson, LaLonde and Sullivan, 1993; Dustmann and Meghir, 2005).

The impact of export activity on wage profiles can reflect human capital accumulation as well as changes in worker-firm rent sharing, as suggested by a large body of quantitative research studying earnings components (e.g., Rubinstein and Weiss, 2006; Burdett, Carrillo-Tudela and Coles, 2011; Bagger et al., 2014; Helpman et al., 2017; Gregory, 2021). Our second contribution is to develop and quantify a dynamic model of multi-worker firms with export-market entry, worker-firm wage bargaining, and human capital accumulation to interpret the data and conduct experiments.

Our model builds on the framework by Cahuc, Postel-Vinay and Robin (2006, henceforth CPR), where firms meet workers by random search. When matched, workers and firms negotiate

the contractual piece rate (the portion of revenues paid to the worker), and workers and firms renegotiate the piece rate when workers are being poached. Workers divide their time between working and human capital accumulation. Guided by our evidence, we embed two novel features into the model. First, we allow the increment in human capital accumulation per time to increase with firm productivity and with the sales-weighted average knowledge about firms' markets.[1] Staying at highly productive firms (which tend to select into exporting) and being exposed to destinations with abundant knowledge can therefore generate faster human capital growth. Second, we consider destinations to be heterogeneous in their knowledge stocks so that different combinations of destinations lead to varying learning opportunities for workers.

In the model, workers' within-job wage profiles reflect human capital growth, changes in time allocated to working, and wage renegotiations. To understand the relative contributions, we calibrate our model to Brazilian manufacturing firms and target relevant moments to discipline the importance of wage bargaining and human capital investment. In the calibrated model, human capital growth can explain 70% of the overall within-job wage profiles. Human capital growth accounts for one-half of the differences in wage profiles between exporters and non-exporters and, among exporters, between the exporters that ship to high-income destinations and those that do not. Diminishing returns to human capital investment mitigate the learning effect. Our calibrated model also matches the observed decline in experience returns after entry into non-high-income destinations.

We then apply our calibrated model to understand the quantitative effects of trade openness. We find that the gain in real income from autarky to the calibrated economy is 7.78%, and a large contributor is human capital formation: workers enjoy a 3.98% increase in labor efficiency due to trade openness. We then perform a decomposition of the trade-induced increase in workers' human capital. Consistent with our empirical evidence, the labor efficiency increase is mostly driven by increased knowledge after firms' entry into high-income destinations. To understand the impact of further trade liberalization, we lower trade costs from Brazil to specific export destinations. We

[1] Monge-Naranjo (2019) and Engbom (2022) also model the dependence of learning returns on firm productivity but do not consider the possibility that human capital gains may vary by the firm's product markets.

find that the gains in real income depend on the knowledge stocks at the destinations and that there can be real-income losses. Lowering trade costs to high-income destinations by 10% would increase Brazil's real income by 1.25%, largely due to a 1.43% increase in workers' human capital. In contrast, lowering trade costs to non-high-income destinations by 10% would reduce Brazil's real income by 0.13%, mainly driven by a 0.75% decline in workers' human capital as firms enter product markets with low knowledge stocks.

This paper relates to several strands of the literature. We directly contribute to the literature on learning by exporting. Recent papers show that through acquiring new knowledge from exporting, firms can improve their technical efficiency (Aw, Roberts and Xu, 2011; De Loecker, 2013; Atkin, Khandelwal and Osman, 2017). Artopoulos, Friel and Hallak (2013) provide case studies in Argentina, showing that export pioneers learn to adopt new practices for foreign markets. Studies also explore how portable knowledge from trade benefits workers and firms, including how firms' import and export choices are related to employees' experience and earnings (Mion and Opromolla, 2014; Muendler and Rauch, 2018; Labanca, Molina and Muendler, 2021). Complementing those studies, we look into how export activity affects workers' wage growth within the firm over time. Our results indicate that exporting may enhance workers' human capital, especially with the exposure to advanced export destinations, and raise earnings.

In studying the earnings evolution, our paper also makes contact with research on life-cycle wage growth. The literature has proposed many factors affecting a worker's earnings over time, including aspects of job search (Bagger et al., 2014) and industry composition (Dix-Carneiro, 2014). There are few studies exploring the role of export participation in life-cycle wage growth. Mion and Ottaviano (2020) find higher wage profiles at internationally active firms than at domestic firms. Our paper explores in addition the relationship between types of export destinations and workers' wage profiles, and we develop a structural model to quantify the aggregate implications. By emphasizing how export destinations affect wage growth through human capital formation, our paper relates to a broad literature on the determinants of on-the-job human capital accumulation (e.g., Manuelli and Seshadri, 2014; De la Croix, Doepke and Mokyr, 2018). We show that the

exporter wage premium over non-exporters increases with the workers' experience, which may partly reflect workers' faster human capital growth at exporters.

The substantive literature on firm-level export dynamics has largely abstracted from labor-market frictions. In a survey, Alessandria, Arkolakis and Ruhl (2021) point to two articles that combine firm dynamics and labor search: Cosar, Guner and Tybout (2016) and Fajgelbaum (2020). One additional publication is Felbermayr, Impullitti and Prat (2018). A recent fourth contribution is Dix-Carneiro et al. (2021), introducing firm informality into the Cosar, Guner and Tybout (2016) model. Fajgelbaum (2020) most closely relates to our paper. Building on the CPR model of search and wage bargaining, as do we, Fajgelbaum (2020) studies the firms' forward looking employment decisions under labor market frictions and prospective export-market entry in the presence of job-to-job search. All four papers abstract from worker heterogeneity and human capital accumulation and cannot generate a wage-tenure profile. Our analysis focuses on the impact of export activity on workers' wage dynamics by experience and accounts for workers' learning and life cycle choices.

Finally, we connect with a large literature on international knowledge diffusion (for a survey see Keller, 2021). Recent theoretical and quantitative papers explore the relation between trade-induced knowledge diffusion and firm productivity growth (e.g., Alvarez, Buera and Lucas, 2013; Perla, Tonetti and Waugh, 2015; Sampson, 2016; Buera and Oberfield, 2020), as reviewed by Lind and Ramondo (2019). That literature typically finds that trade accelerates productivity growth. For example, in a model calibrated to cross-country data, Buera and Oberfield (2020) find that the gains from trade more than double after introducing the diffusion of ideas between competitors. We highlight that workers' human capital accumulation may also reflect trade-induced knowledge flows. Our quantitative analysis suggests that the gains from trade almost double when we introduce workers' human capital formation with exposure to the knowledge at export destinations.

The remainder of this paper is organized as follows. Section II describes our empirical findings and presents the interaction between wage profiles and destination markets. To understand the facts and perform quantitative analysis, Section III develops a firm-level model with export activity in a small open economy, wage bargaining, and human capital accumulation. Section IV calibrates the

model to match the data moments, and Section V performs several counterfactual exercises to study the role of trade openness for human capital formation and real income. Section VI concludes.

# II Experience-Wage Profiles and Exporting

In this section, we present a set of stylized facts on the relationship between export activity and experience-wage profiles in Brazil. We document that experience-wage profiles are steeper at exporters than non-exporters. We then show that steeper experience-wage profiles at exporters reflect both selection of more capable firms into exporting and the effects of exporting to more advanced destinations. We first describe the data.

## II.A Data

We use the administrative matched employer–employee data RAIS (*Relação Anual de Informaçõs Sociais*) between 1994–2010.[2] RAIS offers a complete record of workers employed in the Brazilian formal sector. Firms are required by law to annually provide worker and job-related information to RAIS, and compliance results in the payment of one monthly minimum wage to workers (Menezes-Filho, Muendler and Ramey, 2008). Each record represents a worker-firm-year observation, containing worker ID, firm ID, and worker characteristics including schooling, age, hourly wage, occupation, and additional demographic information. One limitation of the data is the absence of the informal sector. Appendix A.2 discusses the characteristics of the Brazilian informal sector and shows that including informal workers may in fact strengthen our empirical results.

We restrict our empirical analysis to manufacturing firms. They produce tradable goods and have been studied extensively. We focus on full-time male workers aged between 18–65 and employed at firms with at least 10 employees.[3] If a worker has multiple records in a year, we select

[2] We describe the Brazilian economy and export patterns in Appendix A.1.

[3] This restriction on male workers follows Lagakos et al. (2018), as large changes in female labor participation rates over time may imply strong selection efforts by female workers. According to the World Bank's estimates for those aged 15+ in Brazil, the female labor force participation rate increased from 45% in 1994 to 54% in 2010, whereas the male labor force participation rate was relatively stable, changing from 81% to 77% during the same period. The restriction by firm employment makes the sample comparable to that of other countries with similar truncations.

the record with the highest hourly wage (Dix-Carneiro, 2014). Under these restrictions, we obtain a sample of 72 million observations in the period 1994–2010, including 17 million unique worker IDs and 229 thousand unique firm IDs.

We use unique firm IDs to merge the RAIS data with Brazilian customs declarations for merchandise exports collected at SECEX for the years 1994–2010. We define a firm as an exporter in a given year if the firm has at least one reported export transaction in that year. The SECEX data contains destinations and the 8-digit products that each firm exports in each year. For 1997–2000, the data also provides information on export quantity and value (U.S.$), covering 90% of Brazilian officially reported total exports between 1997–2000.[4]

Summary statistics are in Appendix B.1. In Appendix B.2, we use the raw data to present experience-wage profiles in the cross section of firms, showing that workers at exporters have steeper wage profiles than workers at non-exporters. There are identification problems with this first-pass comparison, so we proceed to formally estimate experience-wage profiles.

## II.B Wage Profiles in the Aggregate and by Export Status

### II.B.1 Constructing aggregate experience-wage profiles

We consider a job as a worker-firm match and estimate experience-wage profiles using workers' within-job wage growth, following Bagger et al. (2014). In comparison with the use of wage levels to estimate experience returns (Lagakos et al., 2018; Islam et al., 2019), this approach takes advantage of the panel structure of our employer-employee data—controlling for individual, firm, and match-specific fixed effects that affect wage levels while avoiding the incidental parameters issue (Arellano and Hahn, 2007). Another strength of focusing on within-job wage growth is that it avoids potential wage changes related to job separations. We estimate the following regression:

$$\Delta \log(w_{i,t}) = \sum_{x \in \mathbb{X}} \phi_s^x D_{i,t}^x + (\gamma_{s,t} - \gamma_{s,t-1}) + \epsilon_{i,t}, \tag{1}$$

[4] Appendix Figure D.2 shows that between 1997–2000, each country's and product's share of Brazilian annual exports from our customs data closely matches that in the official data.

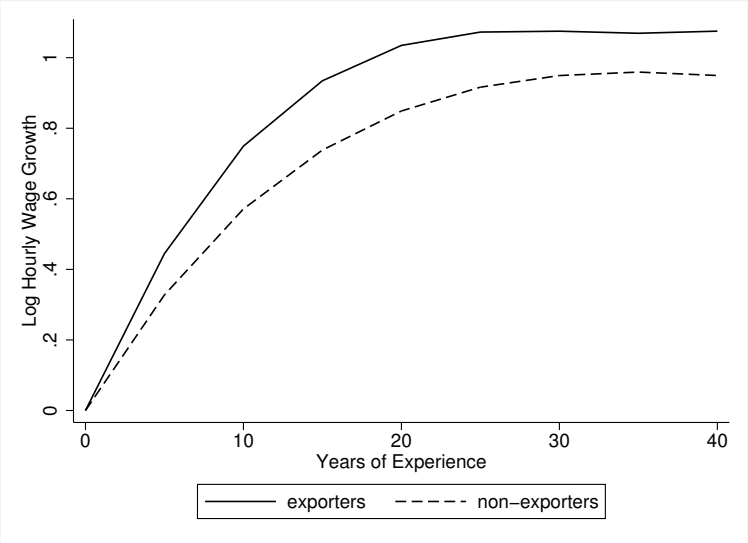
where $i$ and $t$ represent individuals and years respectively. The subscript $s$ is the level of aggregation for estimating experience returns (at exporters and non-exporters), which will be specified in later implementation. $\Delta \log(w_{i,t})$ denotes within-job wage growth, which is the log hourly wage growth from $t-1$ to $t$ for individual $i$ within the same firm.[5]

We cannot observe every worker's full employment history, so we follow Lagakos et al. (2018) and construct a measure of potential experience in the labor market as the minimum between age minus 18 and age minus 6 minus the years of schooling, $\min\{$age-18,age-6-schooling$\}$. $D^x_{i,t}$ is a dummy variable that takes the value 1 if a worker's current potential experience is in experience bin $x \in \mathbb{X} = \{1\text{–}5, 6\text{–}10, ...\}$, where $\mathbb{X}$ is the set of 5-year experience bins. The parameter $\phi^x_s$ measures returns to one additional year of experience for workers in experience bin $x$. We thus allow experience returns to non-parametrically differ across life cycle stages (measured by experience bin $x$), allowing experience returns to change as workers grow older. $\gamma_{s,t}$ represents time effects on wage levels at time $t$, capturing aggregate productivity and price levels.

Equation (1) suffers from the well-known problem of collinearity between experience, individual effects, and time effects (Deaton, 1997): the sum $\sum_x D^x_{i,t} = 1$ is perfectly correlated with the constant $(\gamma_{s,t} - \gamma_{s,t-1})$ for each aggregation level $s$ and time $t$. Intuitively, entering a new year amounts to one more year of experience, and wage growth over time can be induced by experience or by better aggregate economic conditions. To disentangle returns to experience from aggregate trends, we adopt the widely used HLT method (e.g., Huggett, Ventura and Yaron, 2011; Lagakos et al., 2018). This approach restricts experience returns to zero at a worker's old age, drawing on the basic prediction of a large number of theories of life-cycle wage growth that there are negligible experience returns in the final working years (Rubinstein and Weiss, 2006). As a result, workers' wage growth in the final working years reflects only time effects. Implementing the HLT approach requires assumptions on two parameters: the number of years with no experience returns, and the depreciation rate. Following Lagakos et al. (2018), we consider 10 years at the end of the working life (31–40 years of experience) with no experience returns and a 0% depreciation rate, and these

[5] The time effects $\gamma_{s,t} - \gamma_{s,t-1}$ depend on the aggregation level $s$ (exporters and non-exporters), so we also require the corresponding firm status to remain constant from $t-1$ to $t$.

**Figure 1:** Log Hourly Wage Increase by Exporters and Non-exporters




*Notes*: Experience-wage profiles for workers at exporters and non-exporters, from estimating equation (1) on the Brazilian data between 1994–2010. We assume no experience returns in final 10 years. Sources: RAIS employer-employee and SECEX customs data, 1994–2010, restricted to manufacturing firms.

two parameters imply the restriction $\phi_s^{31-35} + \phi_s^{36-40} = 0$. Appendix C.1 provides further details on the approach.

### II.B.2 Experience-wage profiles for workers at exporters and non-exporters

We use equation (1) to estimate experience-wage profiles. We focus on the effects of firms' export activity on wage profiles. We relegate a discussion of the role of the industry composition to Appendix D.1, where we show that industry characteristics do not drive the difference in experience returns between exporters and non-exporters. We always control for industry effects when comparing wage profiles between exporters and non-exporters.[6] Figure 1 presents the estimated experience-wage profiles at exporters and non-exporters. For a hypothetical person staying in a job for 20 years from the beginning of her career, her wage growth is 19 percentage points higher at exporters than at non-exporters, and the difference slightly declines to 14 percentage points after

[6]Specifically, we estimate equation (1) separately for Brazilian workers at exporters and at non-exporters, for each 3-digit industry. We then apply identical weights (total industry-level employment) to construct aggregate profiles for workers at exporters and non-exporters, respectively.

40 years of experience.[7]

## II.C Firm-level Wage Profiles and Export Destinations

### II.C.1 Constructing experience-wage profiles at the firm level

To understand what drives differences in experience returns between exporters and non-exporters, we modify equation (1) to estimate firm-year-level returns to experience,

$$\Delta \log(w_{i,t}) = \sum_{x \in \mathbb{X}} \phi^x_{\omega,t} D^x_{i,t} + (\gamma_{\omega,t} - \gamma_{\omega,t-1}) + \epsilon_{i,t}, \tag{2}$$

where $\omega$ refers to a firm. The returns to one-year experience $\phi^x_{\omega,t}$ are now firm-specific and also time-variant to allow for an exploration of changes in firms' export status. This equation involves a large number of firm-specific parameters and usually requires grouping firms into several groups for estimation (Bonhomme, Lamadon and Manresa, 2019). To exploit the firm-level information, instead of directly estimating equation (2), we make use of the HLT assumption that there are no experience returns for workers in the final 10 years of the working life, $\phi^{31-35}_{\omega,t} + \phi^{36-40}_{\omega,t} = 0$. Based on this assumption, the wage growth of the last two experience bins reflects the firm-specific wage trend $(\gamma_{\omega,t} - \gamma_{\omega,t-1})$.[8] We can therefore construct an estimate for annual returns to experience in experience bin $x$ with

$$\hat{\phi}^x_{\omega,t} = \frac{\sum_{i \in \mathbb{I}(\omega)} D^x_{i,t} \Delta \log(w_{i,t})}{\sum_{i \in \mathbb{I}(\omega)} D^x_{i,t}} - \frac{1}{2} \left( \frac{\sum_{i \in \mathbb{I}(\omega)} D^{31-35}_{i,t} \Delta \log(w_{i,t})}{\sum_{i \in \mathbb{I}(\omega)} D^{31-35}_{i,t}} + \frac{\sum_{i \in \mathbb{I}(\omega)} D^{36-40}_{i,t} \Delta \log(w_{i,t})}{\sum_{i \in \mathbb{I}(\omega)} D^{36-40}_{i,t}} \right), \tag{3}$$

where $\sum_{i \in \mathbb{I}(\omega)} D^x_{i,t} \Delta \log(w_{i,t}) / \sum_{i \in \mathbb{I}(\omega)} D^x_{i,t}$ is the average individual-level wage growth between $t-1$ and $t$, for a worker at firm $\omega$ ($i \in \mathbb{I}(\omega)$) in both periods and in experience bin $x \in \mathbb{X} = \{1\text{–}5, ..., 36\text{–}40\}$. In equation (3) we control for time-varying conditions (such as TFP growth, demand

[7] Appendix Figure D.3 shows that the relative differences in wage profiles between exporters and non-exporters are quantitatively similar if we assume no experience returns in the final 5 years. An alternative value of the depreciation rate shifts exporters' and non-exporters' wage profiles by the same amount and thus does not affect the relative differences.

[8] We use a single term to construct firm-specific wage trends if only one of the two terms $\sum_{i \in \mathbb{I}(\omega)} D^{31-35}_{i,t} \Delta \log(w_{i,t}) / \sum_{i \in \mathbb{I}(\omega)} D^{31-35}_{i,t}$ and $\sum_{i \in \mathbb{I}(\omega)} D^{36-40}_{i,t} \Delta \log(w_{i,t}) / \sum_{i \in \mathbb{I}(\omega)} D^{36-40}_{i,t}$ exists.

shocks) that alter wages for all workers within the firm. For example, if the firm raises every worker's wage by the same proportion under increased revenues after exporting, this common pay raise will not show up in the estimated experience returns of workers at firm $\omega$. However, if the wage growth is relatively higher for young workers than old workers, the differential is interpreted as returns to experience.

### II.C.2 Linking firm-level wage profiles to firm characteristics

In Table 1, we regress firm-year-level returns to 20 years of experience on firm characteristics. The dependent variable is $5 \times \sum_{x \in \{1-5,\ldots,16-20\}} \hat{\phi}^{x}_{\omega,t}$, measuring the hypothetical life-cycle wage growth of a worker staying at firm $\omega$ for 20 years from the beginning of the career, with returns to experience fixed at time $t$. We choose to report returns to 20 years of experience because many firms do not have workers in all experience bins and workers experience minor returns to experience after 20 years of experience (Figure 1).[9]

In Column (1), the predictors are an exporter dummy (1 if a firm exports) and a set of industry and year fixed effects. The reference group is non-exporters. We find that, after 20 years of experience, workers' wage increase is 27 percentage points higher at exporters than at non-exporters, which is comparable in magnitude to the difference found earlier (Figure 1)—19 percentage points after 20 years of experience.

This exporter premium in experience returns may reflect exporters' advantages in workforce composition or unobserved technology (Islam et al., 2019). In Column (2) we control for workers' education (average years of schooling and the share of workers with high-school degree), occupational composition (the shares of production workers and occupations intensive in cognitive tasks), and average age. Because we do not have firm-level production data, we control for firm employment, which is positively associated with firm productivity (Hopenhayn, 1992), and we also control for firms' employment deciles to allow for nonlinear effects.[10] Finally, we control for firm fixed

[9] We can compute returns to 20 years of experience for 36% of firm-year observations, covering 80% of total manufacturing employment in the sample.

[10] The lack of production or value added information renders it impossible to directly estimate the firm's productivity and control for it, which could lead to an omitted-variable problem in our analysis and has to be left to future

**Table 1:** Wage Profiles and Firm Characteristics

| | Dep Var: Firm-year-level Returns to 20 Yrs of Experience | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Sample period | 94–10 | 94–10 | 94–10 | 97–00 | 97–00 | 97–00 |
| Exporter | 0.278*** | 0.021 | -0.015 | -0.051 | -0.071 | -0.037 |
| | (0.013) | (0.030) | (0.035) | (0.073) | (0.127) | (0.126) |
| Exporter × ratio of # high-income to # total dests | | | 0.134*** | 0.239** | | |
| | | | (0.052) | (0.110) | | |
| Exporter × share of exports to high-income dests | | | | | 0.183* | |
| | | | | | (0.104) | |
| Exporter × log(avg GDPPC of dests) | | | | | | 0.128** |
| | | | | | | (0.062) |
| Exporter × log(# total dests) | | | -0.007 | 0.038 | 0.029 | 0.029 |
| | | | (0.020) | (0.053) | (0.060) | (0.060) |
| Exporter × log(avg exports per employee) | | | | | 0.007 | 0.006 |
| | | | | | (0.022) | (0.022) |
| Industry and Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | No | Yes | Yes | Yes | Yes | Yes |
| Controls | No | Yes | Yes | Yes | Yes | Yes |
| Obs | 344,658 | 344,658 | 344,658 | 77,847 | 77,847 | 77,847 |
| R-squared | 0.007 | 0.319 | 0.319 | 0.489 | 0.489 | 0.489 |

*Notes*: Estimates from regressions of firm-year-level returns to 20 years of experience on firm characteristics. Reference group: non-exporters. Controls: average years of schooling; share of workers with high-school degree; share of occupations intensive in cognitive tasks; share of production workers; average worker age; firm employment; and firm employment percentiles (divided into 10 bins) within each industry-year bin. Countries are classified as high-income according to the World Bank in 2000, which sets the high-income threshold at a GNI per capita of US$9,265 in 2000. See Appendix D.2 for several robustness checks to the high-income classification. Robust standard errors in parentheses. Significance levels: * 10%, ** 5%, *** 1%. Sources: RAIS employer-employee and SECEX customs data, 1994–2010, restricted to manufacturing firms.

effects, capturing time-invariant unobserved factors.[11] After including these controls, the resulting exporter premium in experience returns declines (relative to Column (1)) and nearly vanishes, suggesting that higher returns to experience at exporters reflect selection of more capable firms into exporting.[12]

We explore the dependence of wage profiles on export destinations in Columns (3)–(6). In

research.

[11] After controlling for firm fixed effects, estimation of the impact of export activity on wage profiles relies on within-firm changes in export activity over time. In our sample, changes in export activity are non-trivial: conditional on the current year's export status, 3% of non-exporters start exporting in the next year, and 13% of exporters stop exporting in the next year.

[12] Appendix Table D.1 reports how each control variable predicts experience returns. We find that for the decline of the exporter premium in experience returns, only controlling for firm employment accounts for 57% of the overall decline after including all control variables, consistent with the tenet that more productive firms provide higher returns to experience and are more likely to select into exporting.

Column (3), for each exporter in each year, we include the ratio of the number of high-income destinations to the total number of export destinations. We also control for the number of export destinations, as the scope of destinations may matter. We find that firms that export more to high-income destinations exhibit steeper wage profiles. The coefficient suggests that other things held constant, a firm exporting solely to high-income countries exhibits a 13-percentage-point step-up in experience returns compared with a firm exporting solely to middle- and low-income countries.

In Columns (4)–(6), we exploit detailed firm-level data on export values available to us only in the 1997–2000 subperiod. Column (4) replicates the regression of Column (3) for the shorter 1997–2000 subperiod. We still find that exporting to high-income countries increases wage profiles, though the coefficients become noisier due to the smaller sample size. In Column (5), we measure an exporter's exposure to high-income countries by the share of exports to high-income destinations in total exports. We also control for export value per employee, as destination-specific effects may originate from increased revenues due to exporting. In line with previous results, larger shares of exports to high-income destinations predict significantly higher returns to experience. We also find that controlling for export value per employee has little effect on the coefficients. In Column (6), we measure a firm's destination-specific exposure by using export-weighted GDP per capita across export destinations.[13] We find that exporting to destinations with higher income significantly increases returns to experience.

Appendix D.2 provides a set of robustness checks. Among these exercises, we consider different classifications of high-income destinations and show that our findings in Table 1 are robust.

[13]To avoid that time trends of GDP drive our results, we use each country's GDP per capita in 2000 to compute the firms' export-weighted GDP per capita across export destinations in 1997–2000. Appendix Table D.2 shows that the empirical findings are similar when we use each year's country-level GDP per capita to construct export-weighted GDP per capita across destinations.

## II.D Changes in Profiles Around Entry to High-income Destinations

### II.D.1 Event study

In Appendix D.3, we perform an event study regarding firm entry into high-income destinations. We find that, after firms' first shipment to a high-income export market, returns to experience increase by 20 percentage points, a statistically significant effect at conventional confidence levels, whereas experience-wage profiles do not statistically significantly shift prior to export entry. The increase in returns to experience stays roughly constant past first entry, indicating that exporting to high-income destinations is associated with persistently higher experience returns. We find no statistically significant changes in experience returns after entry into non-high-income destinations.

### II.D.2 Propensity score matching estimator

Entry into export activity can be endogenous. To control for self-selection into exporting, in Appendix D.4 we apply a propensity-score matching estimator (Heckman, Ichimura and Todd, 1997). The idea of the matching estimator is to choose an appropriate group of non-exporters as control group, based on predicted export probabilities. We first estimate each firm's probability to start to export, while controlling for a broad range of pre-exporting firm characteristics, and then choose the control group based on nearest-neighbor matching. The identifying assumption is that controlling for an exhaustive set of firm-level characteristics turns observed export-market entry into a random event unrelated to any systematic firm attribute. The estimation results suggest that exporting to high-income destinations raises returns to experience. Most of the estimated increases in returns to 20 years of experience are significant and at around 20 percentage points, similar to our previous findings. For entry to non-high-income destinations, we find no statistically significant changes in returns to experience after export entry.

### II.D.3 Brazilian currency crisis

Recent studies exploit substantive currency devaluations as quasi-experiments to study the causal impact of export entry on firm performance (e.g., Verhoogen, 2008). In Appendix D.5, we use the Brazilian currency crisis in 1999 when the Brazilian Real experienced a 60% devaluation against the U.S. dollar within two months. We show that the currency devaluation encouraged more export entry. We also find significantly higher returns to experience for firms that exported to high-income destinations following this currency crisis, after controlling for pre-exporting export patterns.

## II.E Worker-level Results

In Appendix D.6, we construct a panel of young workers that first appear in RAIS within 5 years after completing school.[14] Using this sample, we still find that previous experience at exporters (especially at those selling to high-income markets) is more valuable than experience at non-exporters, and that these experience effects are largely portable when workers switch firms. The estimated experience effects are of a similar magnitude to our previous findings. We also show similar results for workers displaced when large firms suddenly close down.

The similarity between worker-level and firm-level results, and across different estimation methods, contributes to our confidence that steeper experience-wage profiles at exporters (than at non-exporters) reflect the effect of a firm's entry into more advanced export destinations.

# III Model

To isolate factors behind the impact of export activity on wage profiles and to assess the aggregate implications, we develop a quantitative model. Motivated by our evidence and the quantitative literature on earnings dynamics, we posit that wage profiles reflect human capital formation as well

[14] This restricted sample has two advantages. First, instead of constructing potential experience, we can now construct these young people's experience using their observed employment history in RAIS. Second, breaks in employment history for reasons such as unemployment (which does not necessarily contribute to more experience) circumvent a collinearity problem between experience and year effects. We therefore no longer need the HLT approach in estimation.

as changes in worker-firm rent sharing. We focus on a steady state in which aggregate variables are constant. We index workers by $i$ and firms by $\omega$ or $\nu$.

## III.A Model Setup

### III.A.1 Workers

**Age structure.** Overlapping generations of workers participate in the labor market at age $a = 1, 2, .., A$. Workers of age $A$ retire at the end of each period and are replaced with a cohort of entering workers of age 1. Each cohort's size is normalized to 1 so that the total population is $A$. The introduction of a workers' age structure equips the model with the dynamics to generate wage profiles comparable to our empirically constructed wage profiles. Moreover, returns to human capital accumulation decline with age and most senior workers enjoy good bargaining positions, so our model generates numerically minor experience effects in the final working years, which is a key assumption of the HLT approach.

**Utility.** Workers enjoy linear utility from consumption of a nontraded final good, and they discount the future at rate $\rho$. The final good is composed of differentiated varieties sourced from domestic or foreign origins, as described below.

**Labor market search.** Labor markets are subject to search frictions. At the beginning of each period, existing jobs are terminated at an exogenous rate $\kappa$. New entrants of age 1 begin their careers as unemployed individuals. Unemployed and employed persons randomly meet job vacancies at the respective rates $\lambda_U$ and $\lambda_E$. Let $U$ be the measure of unemployed persons prior to job search, and $\eta \in [0, 1)$ the search effort of employed persons relative to the unemployed, whose search effort is normalized to 1. The meeting rates $\lambda_U$ and $\lambda_E$ are endogenously determined: $\lambda_U = \chi\left(V/[U + \eta(A - U)]\right)$ and $\lambda_E = \eta\lambda_U$, where $V/[U + \eta(A - U)]$ is the ratio of firms' vacancies to total search efforts. The function $\chi(\cdot)$ governs the matching process (we specify its form in Section IV.B).

When an unemployed worker meets a job vacancy, she accepts the job with certainty under the assumption that unemployment is equivalent to employment at the least productive firm. Similar to Bagger et al. (2014), this assumption avoids the complication of heterogeneous reservation wages for workers of different human capital levels and ages. Unemployment lasts if the unemployed person does not meet a vacancy. When an employed worker meets a job vacancy, the employed worker may move to the poaching firm if the poaching offer is more attractive than the current job, as described in subsection III.B.1 below.

**Wage.** At firm $\omega$, wages differ between workers. A worker $i$ of age $a$ receives a wage

$$w_i^a(\omega) = r_i(\omega)\tilde{z}(\omega)\left[h_i^a - s^a(h_i^a, \omega)\right], \tag{4}$$

where $\tilde{z}(\omega)$ is firm $\omega$'s revenue per unit of efficiency labor in the current period, $h_i^a$ is worker $i$'s human capital (total units of efficiency labor), and $s^a(h_i^a, \omega)$ is the optimal time (in terms of units of labor) spent on human capital accumulation, to be derived in subsection III.B.3 below. As in Bagger et al. (2014), the worker and the firm negotiate the contractual piece rate $r_i(\omega)$, where $r_i(\omega) \in [0, 1]$ can be viewed as the portion of revenues generated by worker $i$ at firm $\omega$ and accruing to the worker. The portion is worker-firm-specific and depends on the history of wage bargaining between worker $i$ and firm $\omega$ over the job surplus, as described below.

**Human capital accumulation.** For tractability, we restrict our attention to a single dimension of general human capital.[15] New entrants of age 1 are endowed with human capital normalized to $h_i^1 = 1$. Employed workers may accumulate human capital on the job. We assume that a worker's human capital evolves from age $a$ to age $a + 1$ with

$$h_i^{a+1} = (1 - \delta_h)h_i^a + \phi^E(\omega)s^a(h_i^a, \omega)^\alpha, \tag{5}$$

[15]Firm-specific components of human capital have been found to be less relevant for wage growth than general human capital (e.g., Lazear, 2009). Our worker-level evidence suggests that most of the human capital gained at exporters is portable when workers switch firms. A focus on general human capital is common in the literature on earnings dynamics (e.g., Bagger et al., 2014; Manuelli and Seshadri, 2014).

where $\delta_h$ is the depreciation rate, $\phi^E(\omega)$ captures the increment in human capital per unit of time spent on building skills, and the power $\alpha \in (0,1)$ regulates the diminishing marginal benefits of time $s^a(h_i^a, \omega)$ for human capital accumulation. A key feature of our model is the dependence of the increment in human capital on the firm's choice of export destinations:

$$\phi^E(\omega) = \mu\, z(\omega)^{\gamma_1}\, \phi^O(\omega)^{\gamma_2}, \tag{6}$$

which is a Cobb-Douglas function of knowledge inside and outside the firm, similar to Monge-Naranjo (2019), where $\gamma_1$ and $\gamma_2$ represent the respective elasticities of the increment to internal and external knowledge. We use firm productivity $z(\omega)$ to proxy internal knowledge—the stock of productive ideas within the firm. $\phi^O(\omega)$ bundles the outside set of productive ideas in the firm's markets and is available to workers at the firm. Let $k_n(\omega)$ be the share of output sold to destination $n$ in the firm's total output, and $\Lambda_n$ denote the stock of knowledge accessible when selling to market $n$. Then $\phi^O(\omega) = \sum_n k_n(\omega)\Lambda_n$ is a weighted average of knowledge across destinations. Appendix E.1 further discusses this learning function and its relationship to the literature.

### III.A.2 Firms

**Firm productivity.** There is a mass $\bar{M}$ of monopolistically competitive firms. Without loss of generality, we normalize $\bar{M} = 1$. Each firm $\omega$ draws productivity $z(\omega)$ from a distribution $\Phi(z)$, and firm productivity is time-invariant. Each firm produces a unique variety using labor. For a firm with productivity $z(\omega)$, producing one unit of its variety requires $1/z(\omega)$ efficiency units of labor. Varieties are internationally traded and aggregated into a nontraded final good in each country with a constant elasticity of substitution $\sigma$ across varieties.

**Trade.** There are countably many countries $n = 1, 2, ..., N$. The home country is the first market $n = 1$, and all other markets are foreign destinations. The home country is a small open economy so that aggregate variables in foreign countries are invariant to conditions at home. Under monopolistic competition and a constant elasticity of substitution between varieties $\sigma$, the demand

for a firm $\omega$'s variety in market $n$ is $y_n(\omega) = p_n(\omega)^{-\sigma} P_n^{\sigma} Y_n$, where $P_n$ and $Y_n$ are the aggregate price index and quantity of the final good in market $n$. The price of a variety in market $n$ is $p_n(\omega) = y_n(\omega)^{-\frac{1}{\sigma}} P_n Y_n^{\frac{1}{\sigma}}$, and the revenue in market $n$ is $p_n(\omega) y_n(\omega) = y_n(\omega)^{\frac{\sigma-1}{\sigma}} P_n Y_n^{\frac{1}{\sigma}}$. When selling to market $n$, firms in the home country incur an iceberg transport cost $\tau_n$ as well as a fixed cost $f_n$ in terms of final goods in the home market. We assume no trade costs of selling to the home market ($\tau_1 = 1$ and $f_1 = 0$).

**Hiring costs.** Firms post vacancies to meet workers. Posting $v$ vacancies costs $c_v v^{1+\gamma_v}/(1+\gamma_v)$ units of final goods. In the quantitative analysis, we assume $\gamma_v > 0$. This assumption generates an exporter premium because it is increasingly costly to hire additional workers so that a firm needs to generate additional revenues per worker to expand. Let $v(\omega)$ be the optimal number of vacancies for firm $\omega$, as detailed below. The total number of vacancies is $V = \int v(\omega)\, \mathrm{d}\Phi(z(\omega))$. We define $F(z(\omega)) = \int_{z_{\min}}^{z(\omega)} v(\nu)\, \mathrm{d}\Phi(z(\nu))/V$ as the offer distribution.

**Firm revenue.** Aggregating over destinations, we can compute the firm's total revenue (gross of fixed export costs) as $\sum_n y_n(\omega)^{\frac{\sigma-1}{\sigma}} P_n Y_n^{\frac{1}{\sigma}}$, where $y_n(\omega)$ is the value of exports to market $n$ (zero if no sales at $n$). In its optimal export entry and export volume decisions, the firm takes into account: (1) total output given by $z(\omega)h(\omega)$, where employment $h(\omega) = \sum_a \int_{i \in \mathbb{I}(\omega)} (h_i^a - s^a(h_i^a, \omega)) \mathrm{d}i$ is the measure of efficiency units employed at firm $\omega$ across workers of different ages; (2) the iceberg and fixed export costs $\tau_n$ and $f_n$; and (3) the impact of export destinations on workers' human capital, which affects the future job surplus. We will specify the firm's choice of export destinations in subsection III.C below. With a slight abuse of notation, we define the revenue per efficiency unit of labor $\tilde{z}(w) \equiv \sum_n y_n(\omega)^{\frac{\sigma-1}{\sigma}} P_n Y_n^{\frac{1}{\sigma}}/h(\omega)$, which plays the role of labor productivity in our model.

## III.B Solving for a Worker's Wage and Human Capital Investment

### III.B.1 Wage bargaining and job-to-job moves

As described in equation (4), a worker's wage is $w_i^a(\omega) = r_i(\omega)\tilde{z}(\omega)\left[h_i^a - s^a(h_i^a, \omega)\right]$, where the piece rate $r_i(\omega)$ is the share of revenues accruing to the worker. The piece rate is worker-firm specific and depends on the worker-firm bargaining history. We now describe the process that determines $r_i(\omega)$, following CPR. The vector $\mathbf{x}(\omega) = \left(z(\omega), \{y_n(\omega)\}_n, \{h_i^a\}_{i\in\mathbb{I}(\omega)}\right)$ collects the firm-level state variables, including productivity, export status, and characteristics of the firm's workforce $\mathbb{I}(\omega)$. These state variables are given when the worker and firm bargain and determine the revenue per labor $\tilde{z}(\omega)$ and human capital increment $\phi^E(\omega)$.[16] We denote with $V^a(r, h_i^a, \mathbf{x}(\omega))$ the value of a job for worker $i$ of age $a$ with piece rate $r$. We denote the joint (worker + firm) value of the job with $M^a(h_i^a, \mathbf{x}(\omega))$, which does not depend on $r$ because the worker's piece rate only determines the distribution of surplus between worker and firm but not the total.

**Unemployed persons.** When an unemployed person $i$ meets and accepts a job at firm $\omega$, the person engages in Nash bargaining with the employer over the job surplus $M^a(h_i^a, \mathbf{x}(\omega))$. The outside option of the worker is the unemployment value $V_U^a(h_i^a)$, whereas the outside option for the firm is set to 0. We assume that the worker's bargaining power is $\beta \in (0, 1)$. The piece rate $r$ maximizes

$$\max_r \left[V^a(r, h_i^a, \mathbf{x}(\omega)) - V_U^a(h_i^a)\right]^\beta \left[M^a(h_i^a, \mathbf{x}(\omega)) - V^a(r, h_i^a, \mathbf{x}(\omega))\right]^{1-\beta}. \tag{7}$$

Optimality implies a piece rate $r$ that satisfies the first-order condition $V^a(r, h_i^a, \mathbf{x}(\omega)) = V_U^a(h_i^a) + \beta\left[M^a(h_i^a, \mathbf{x}(\omega)) - V_U^a(h_i^a)\right]$. The worker receives the outside value of unemployment plus a por-

[16] In our model, export decisions are separate from the bargaining process. In practice, firm divisions responsible for product and sales decisions may plausibly be distinct from those responsible for human resources and thus the worker contracting and bargaining process. The assumption helps with computational tractability. Our bargaining and contracting setup involves the worker-related wage and work time choices but differs from the comprehensive contracts in the Menzio and Shi (2011) model, where the worker and the firm also contract over payoff-relevant decisions on the firm side.

tion $\beta$ of the extra value of holding a job relative to unemployment $M^a(h_i^a, \mathbf{x}(\omega)) - V_U^a(h_i^a)$. We discuss the explicit expressions for $V^a(r, h_i^a, \mathbf{x}(\omega))$, $V_U^a(h_i^a)$ and $M^a(h_i^a, \mathbf{x}(\omega))$ below.

**On-the-job searchers.** After accepting the job, an employed person's piece rate $r$ does not change over time until there is an outside offer from a poaching firm denoted by $\nu$. When there is an outside offer, there are three scenarios with different implications for a revision of the employed person's piece rate.

1. The poaching firm $\nu$ cannot offer the worker a value higher than the worker's current value, so that $V^a(r, h_i^a, \mathbf{x}(\omega)) > M^a(h_i^a, \mathbf{x}(\nu))$. In this case, the outside offer does not affect the worker's wage and the piece rate $r$ does not change.

2. The job at the poaching firm $\nu$ is more valuable than the worker's current job at firm $\omega$, so that $M^a(h_i^a, \mathbf{x}(\nu)) > M^a(h_i^a, \mathbf{x}(\omega))$. In this case, the worker moves to the poaching firm. For wage bargaining at the poaching firm, the worker's outside option is the job value at the current firm $M^a(h_i^a, \mathbf{x}(\omega))$. Nash bargaining determines the piece rate $r'$ at the poaching firm:

$$\max_{r'} \left[V^a(r', h_i^a, \mathbf{x}(\nu)) - M^a(h_i^a, \mathbf{x}(\omega))\right]^{\beta} \left[M^a(h_i^a, \mathbf{x}(\nu)) - V^a(r', h_i^a, \mathbf{x}(\nu))\right]^{1-\beta}. \tag{8}$$

   Optimality implies that the piece rate $r'$ at the poaching firm $\nu$ satisfies the first-order condition $V^a(r', h_i^a, \mathbf{x}(\nu)) = M^a(h_i^a, \mathbf{x}(\omega)) + \beta \left[M^a(h_i^a, \mathbf{x}(\nu)) - M^a(h_i^a, \mathbf{x}(\omega))\right]$.

3. The job at the current firm $\omega$ is more valuable than the job at the poaching firm $\nu$, but the value of employment is so low that the poaching firm's offer is attractive to the worker because $V^a(r, h_i^a, \mathbf{x}(\omega)) < M^a(h_i^a, \mathbf{x}(\nu)) < M^a(h_i^a, \mathbf{x}(\omega))$. To prevent the worker from separating, the current firm renegotiates with the worker over a new division of the job surplus. The worker now uses the poaching firm's job value $M^a(h_i^a, \mathbf{x}(\nu))$ as the outside option. The worker stays at the current firm and receives the new piece rate $r'$ under Nash bargaining similar to equation (7), where instead of the value of unemployment the worker uses the poaching firm's job value

as outside option. Optimality implies that the new piece rate $r'$ satisfies $V^a(r', h_i^a, \mathbf{x}(\omega)) = M^a(h_i^a, \mathbf{x}(\nu)) + \beta\left[M^a(h_i^a, \mathbf{x}(\omega)) - M^a(h_i^a, \mathbf{x}(\nu))\right]$.

### III.B.2 Value of employment

We present the formula for the value of employment in Appendix E.2. $V^a(r, h_i^a, \mathbf{x}(\omega))$ is a function of the current wage $r\tilde{z}(\omega)(h_i^a - s^a(h_i^a, \omega))$ and its future value, which depends on human capital in the next period given by equation (5) and on whether the worker stays or leaves the firm. The unemployment value is $V_U^a(h_i^a) = \min_\omega M^a(h_i^a, \mathbf{x}(\omega))$. At the conclusion of the bargaining process, the firm and the worker contract on a specific piece rate $r$ that delivers the value of employment.[17]

### III.B.3 Job value and human capital investment

**Job value.** To solve for human capital investment, we need to specify the joint (firm + worker) value of a job. In Appendix E.2 equation (E.2), we show that the job value includes current firm revenues generated by the involved worker $\tilde{z}(\omega)(h_i^a - s^a(h_i^a, \omega))$ and the future job value. The difference between the job value and the value of employment is the firm's value of the job, which mainly captures the portion of current and future revenues generated by the worker and accruing to the firm.

**Human capital investment.** We assume that the worker and the firm jointly choose the time spent on human capital accumulation $s^a(h_i^a, \omega)$ to maximize the job surplus $M^a(h_i^a, \mathbf{x}(\omega))$ similar to Acemoglu and Pischke (1999), while the worker and the firm simultaneously bargain over the split of the maximal surplus. Using the evolution of human capital (5) in the joint job value (E.2),

[17] CPR analytically solve for the piece rate and show that it increases with the worker's current outside option and depends on the history of the worker's outside offers from poaching firms. Our model with endogenous human capital formation does not yield an analytical solution for the piece rate. We therefore rely on numerical analysis to first solve for the value of employment at any piece rate $r$ and then find the specific piece rate that delivers the value determined by the worker's bargaining outcome.

the first-order condition for the optimal time spent on human capital accumulation implies

$$s^a(h_i^a,\omega)=\left(\frac{\alpha\phi^E(\omega)}{\tilde{z}(\omega)}\frac{\partial M^a(h_i^a,\mathbf{x}(\omega))}{\partial h_i^{a+1}}\right)^{\frac{1}{1-\alpha}}. \tag{9}$$

The optimal time spent on human capital accumulation increases with marginal benefits, which are determined by the human capital increment per time $\phi^E(\omega)$ and the marginal return of human capital $\partial M^a(h^a,\mathbf{x}(\omega))/\partial h^{a+1}$. Exporting to destinations with high knowledge stocks leads to a higher value of $\phi^E(\omega)$ and thus encourages human capital investment. As workers grow older, the gains of human capital accumulation tend to decline. In particular, for a worker who retires at the end of a period (so the next-period value is 0), $\partial M^a(h^a,\mathbf{x}(\omega))/\partial h^{a+1}=0$. As a consequence, there is no human capital investment one period before retirement, and our model can numerically generate vanishing experience effects in the final working years.

## III.C Solving for a Firm's Export Entry by Destination and Vacancy Posting

To account for the impact of firms' export destinations on workers' human capital accumulation, we posit that the firm's export destinations are chosen to maximize the total job value aggregated over workers within the firm, net of fixed export costs:

$$\begin{aligned}
&\max_{\{y_n(\omega)\}}\sum_a\int_{i\in\mathbb{I}(\omega)}M^a(h_i^a,\mathbf{x}(\omega))\,\mathrm{d}i-\sum_n\mathbf{1}_{\{y_n(\omega)>0\}}P_1f_n\\
&\quad=\underbrace{\sum_n\mathbf{1}_{\{y_n(\omega)>0\}}\left(y_n(\omega)^{\frac{\sigma-1}{\sigma}}P_nY_n^{\frac{1}{\sigma}}-P_1f_n\right)}_{\text{revenues net of fixed export costs}}+\underbrace{\sum_a\int_{i\in\mathbb{I}(\omega)}M^{a,future}(h_i^a,\mathbf{x}(\omega))\,\mathrm{d}i}_{\text{future job value}}\\
&s.t.\ \underbrace{\sum_n\tau_ny_n(\omega)=z(\omega)h(\omega),}_{\text{output capacity}}\qquad\underbrace{\mathbf{x}'(\omega)=\Gamma(\mathbf{x}(\omega))}_{\text{law of motion for firm's state}},
\end{aligned} \tag{10}$$

where $\mathbf{1}_{\{y_n(\omega)>0\}}\in\{0,1\}$ indexes the decision of exporting to market $n$. The second line is obtained by decomposing the job value $M^a(h_i^a,\mathbf{x}(\omega))$ into the current revenue and the future value

$M^{a,future}(h_i^a, \mathbf{x}(\omega))$.[18] Compared with the static problem of maximizing trade revenues net of fixed costs (Melitz, 2003), we also take into account the impact of export destinations on the future job value through workers' human capital, by incorporating workers' future value into the choice of export destinations.

In the presence of convex vacancy costs, firms face increasing marginal costs of hiring workers, and thus firms' export decisions are interdependent across destination markets. Thus, our model implies a permutation problem for deciding the set of export destinations from all feasible combinations, similar to Tintelnot (2017) who studies the permutation problem of how to structure multinational production. In total, there are $2^N - 1$ feasible combinations of destination markets ($\mathbf{1}_{\{y_n(\omega)>0\}} \in \{0, 1\}$ for each market $n = 1, ..., N$). To solve the choice of export destinations, we first evaluate the benefit in equation (10) given each feasible combination of export destinations and then choose the optimal combination of export markets that delivers the highest benefit.

In Appendix E.3, we show that the optimal amount of vacancies is determined such that the marginal costs of posting a vacancy equal the aggregate value per vacancy from hiring unemployed workers and poaching employed workers.

## III.D General Equilibrium

The analysis so far studies the export activity of firms in the home country. To close the model, we assume that the home country imports a fixed number $\bar{M}^I$ of varieties with unit price $p^I$. We do not allow for savings, so all firm profits (revenues net of fixed export costs) and labor earnings are spent on final goods. Balanced trade requires that, when the goods market clears, the firms' total export value equals the total value of imported varieties in the home country. In Appendix E.4, we provide a detailed equilibrium definition.

[18] Specifically, we have $M^{a,future}(h_i^a, \mathbf{x}(\omega)) = M^a(h_i^a, \mathbf{x}(\omega)) - \tilde{z}(\omega)(h_i^a - s^a(h_i^a, \mathbf{x}(\omega)))$.

## III.E Export Activity and Wage Profiles

Using wage equation (4), a worker $i$'s within-job wage growth at firm $\omega$ is

$$\Delta \log w_i^a(\omega) = \underbrace{\Delta \log h_i^a}_{\text{change in human capital}} + \underbrace{\Delta \log \left(1 - \frac{s^a(h_i^a, \omega)}{h_i^a}\right)}_{\text{change in work time}} + \underbrace{\Delta \log \tilde{z}(\omega)}_{\text{change in labor productivity}} + \underbrace{\Delta \log r_i(\omega)}_{\text{change in piece rate}} . \tag{11}$$

Export activity changes wage profiles within the firm through four channels. First, export activity affects workers' human capital increment, by shifting the mixture of destinations to which workers are exposed under equation (6). Workers' human capital growth depends on the external environment ($\gamma_2 > 0$), and knowledge stocks $\Lambda_n$ vary across destination markets, so export activity alters wage profiles through the human capital channel. Second, due to changes in human capital investment, workers' work time also changes. Young workers spend more time on human capital accumulation than old workers, so work time increases over the life cycle, and thus changes in work time move wage profiles. Third, firms' labor productivity $\tilde{z}(\omega)$ moves wages directly (in a generalized model export activity could affect inherent productivity in addition). The labor productivity change is identical for young and old workers within a firm and thus does not directly affect wage profiles. However, increased labor productivity offers larger room for the current workers' wages to grow through wage renegotiations when workers, especially young, are poached by outside firms. The fourth term reflects resulting changes in the piece rate from renegotiation.

The impact of export activity on wage profiles matters for the aggregate economy. In Appendix E.5 we show that, under certain assumptions, the gains from trade in our model can be decomposed into changes in real income per efficiency labor, which resembles the well-studied formula (e.g., Arkolakis, Costinot and Rodríguez-Clare, 2012; Costinot and Rodríguez-Clare, 2014), and changes in the average level of employees' efficiency labor. Changes in the human capital of workers reflect both the impact of export destinations on wage profiles and workers' reallocation toward exporters where workers may enjoy faster human capital accumulation.

In our computational implementation of the model, we consider steady state and do not incor-

porate transitional dynamics in export status or revenues.[19]

# IV Quantification

In this section, we calibrate our model to the Brazilian data. Through the lens of our quantitative model, we then explore the determinants of within-job wage profiles.

## IV.A Data

We match the model to summary statistics from the employer-employee data and the customs data of the Brazilian formal manufacturing sector between 1994–2010. As discussed in Section III.E, within-job wage profiles in our model reflect changes in human capital accumulation as well as changes in worker-firm bargaining positions due to wage renegotiations. Thus, the core variables that we use are job-to-job transitions and the slope of wages on firm employment, which are informative of on-the-job search intensity and workers' bargaining power, governing the strength of wage renegotiations. Combining information on wage renegotiations, we use the within-job wage profiles to discipline the magnitude of human capital accumulation.

In our model, because of convex hiring costs, export decisions are interdependent across destination markets. To compute a firm's export decision, we need to compare $2^N - 1$ feasible combinations of $N$ destination markets—a computationally demanding procedure for large $N$. We therefore aggregate all destination markets (other than Brazil) into their continents and whether they are high-income countries. We obtain $N = 10$ groups of destinations, including Brazil, high-income countries in Europe, Asia, North America, and Oceania, and non-high-income countries in Europe, Asia, North America, Africa, and South America.[20]

[19] We found the model to be computationally intractable when firms and workers are both forward-looking and form expectations of firms' future productivity shocks for their decisions. When we quantitatively compute gains in experience returns immediately following export entry, we use a partial-equilibrium analysis similar to recent research (Buera, Kaboski and Townsend, 2021), implementing alternative realizations of export costs for each firm in steady state.

[20] Africa and South America do not have high-income countries. Non-high-income countries in Oceania account for a negligible share (less than 0.01%) of the Brazilian manufacturing exports in 2000, so we omit them from the analysis.

## IV.B Calibration

To proceed, we specify the function $\chi(\cdot)$ that determines the meeting rate between unemployed persons and firms. It is common to use a Cobb-Douglas job matching function between searchers and vacancies (e.g., Shimer, 2005), which implies $\chi(x) = c_M x^{\phi}$, where $0 < \phi < 1$ is the elasticity of job matches to vacancies. To capture the idea that some small firms also export, we assume that time-invariant export fixed costs $\{f_n\}_{n=2,\ldots,N}$ follow a log-normal distribution, $\log f_n \sim \mathcal{N}(\log \bar{f}_n, \sigma_f^2)$, i.i.d. across firms and destinations. Our model does not allow for firm-level export shocks in each period because modeling both labor market dynamics and stochastic changes in firm exports would make the model intractable.[21] Finally, it is common in the trade literature (e.g., Chaney, 2008) to assume a Pareto productivity distribution $\Phi(z) = 1 - z^{-\zeta}$, with a larger shape parameter $\zeta$ implying less productivity dispersion.

The calibration must determine the following parameters: the worker's lifetime $A$, the discount rate $\rho$, the number of destinations $N$, the parameters governing labor search and wage bargaining $\{\phi, c_M, \kappa, \eta, \beta\}$, human capital depreciation and returns $\{\delta_h, \alpha, \mu, \gamma_1, \gamma_2, \Lambda_n\}$, the shape parameter $\zeta$ of the productivity distribution, the elasticity of substitution between varieties $\sigma$, the demand and fixed costs of foreign markets $\{P_n^{\sigma} Y_n \tau_n^{1-\sigma}, \bar{f}_n, \sigma_f\}_{n=2,\ldots,N}$, the constant and curvature of vacancy costs $\{c_v, \gamma_v\}$, and import demand $\bar{M}^I (p^I)^{1-\sigma}$.

### IV.B.1 Parameter choices prior to solving the model

Panel A of Table 2 lists the parameters that we set without solving the model. We calibrate a model of annual frequency and pick an annual discount rate $\rho$ of 0.04. Every person works for 40 years at most, so we set the total work time to $A = 40$ years.

We set the elasticity of job matches to vacancies to $\phi = 0.3$ following Shimer (2005)'s estimate for the U.S. economy. This parameter is commonly applied to other countries in the development literature (e.g., Feng, Lagakos and Rauch, 2018). We follow Manuelli and Seshadri (2014) and

[21] Under stochastic export-market conditions, the worker would need to form expectations about firms' future export status, and the firm would need to take into account the workers' different turnover rates under a varying export status.

**Table 2:** Parameters Values

| Parameter | Notation | Value | Source |
|---|---|---|---|
| *Panel A: Parameter Choices Prior to Solving the Model* | | | |
| Total work time (years) | $A$ | 40 | |
| Discount rate | $\rho$ | 0.04 | |
| Number of destination markets | $N$ | 10 | Authors' country grouping |
| Elasticity of matches to vacancies | $\phi$ | 0.3 | Shimer (2005) |
| Depreciation of human capital | $\delta_h$ | 0.02 | Manuelli and Seshadri (2014) |
| Convexity in production of human capital | $\alpha$ | 0.48 | Manuelli and Seshadri (2014) |
| Stock of knowledge ($n = 1, ..., N$) | $\Lambda_n$ | 1.99 (1.25) | Data on GDP per capita |
| Elasticity of substitution | $\sigma$ | 5 | Head and Mayer (2014) |
| Curvature of vacancy costs | $\gamma_v$ | 1.5 | Dix-Carneiro et al. (2021) |
| *Panel B: Parameters Calibrated by Solving the Model* | | | |
| Constant in matching function | $c_M$ | 0.76 | |
| Job destruction rate | $\kappa$ | 0.16 | |
| On-the-job search intensity | $\eta$ | 0.12 | |
| Constant in human capital increment | $\mu$ | 0.07 | |
| Constant in vacancy costs | $c_v$ | 0.02 | |
| Workers' bargaining power | $\beta$ | 0.60 | |
| Elasticity of human capital increment to productivity | $\gamma_1$ | 0.27 | |
| Elasticity of human capital increment to market knowledge | $\gamma_2$ | 0.21 | |
| Shape parameter of productivity distribution | $\zeta$ | 4.10 | |
| Export demand (by destination, $n = 2, ..., N$) | $P_n^\sigma Y_n \tau_n^{1-\sigma}$ | 37.86 (24.47) | |
| Export fixed costs (by destination, $n = 2, ..., N$) | $\bar{f}_n$ | 0.28 (0.19) | |
| Standard deviation of export costs | $\sigma_f$ | 1.48 | |
| Import demand | $\bar{M}^I (p^I)^{1-\sigma}$ | 0.14 | |

*Notes*: The stock of knowledge is the average across 10 destination markets including Brazil, with the standard deviation in parentheses. The values for export demand $P_n^\sigma Y_n \tau_n^{1-\sigma}$ and export fixed costs $\bar{f}_n$ are averages across 9 foreign markets, with the standard deviation in parentheses. Demand depends on a standardization: we normalize the domestic price index to $P_1 = 1$ in the calibrated equilibrium. In a standard Melitz-Chaney model with a competitive labor market (Chaney, 2008), $\zeta > \sigma - 1$ is required to ensure that the aggregation of sales across firms is finite. Compared with the standard model, our model has two main differences (labor market frictions and human capital accumulation) that may loosen or tighten this requirement. Given the difficulty of analytically solving the exact requirement for the finite aggregation of sales in our model, we require $\zeta > \sigma - 1$ in the calibration.

use the depreciation of human capital $\delta_h = 0.02$ and the convexity in the production of human capital $\alpha = 0.48$. We proxy each country's knowledge stock $\Lambda_n$ by its GDP per capita in 2000 and aggregate countries into our $N = 10$ groups using Brazil's export values in 2000 as country weights within groups. We normalize Brazil's knowledge stock to 1.

We set the elasticity of substitution between varieties to $\sigma = 5$, a common value in the trade literature (Head and Mayer, 2014). For the convexity in vacancy costs we use $\gamma_v = 1.5$ using Dix-Carneiro et al. (2021)'s estimate for Brazilian firms.

### IV.B.2 Parameters calibrated by solving the model

We jointly estimate the remaining 29 parameters (listed in Panel B of Table 2) to match 29 data moments on trade, the labor market, and wage profiles. We report the moments used in our calibration in Appendix Table F.1.

To ensure consistency between the model-generated data and our empirical analysis, we compute experience returns (returns to 20 years of experience) in the model applying the same HLT method as discussed in Section II.C. Importantly, we target the key empirical result—the increase in experience returns after export entry into high-income destinations—and use the average from reduced-form results based on the matching estimator in Appendix Table D.11. In the model, we implement alternative realizations of export fixed costs $f_n$ for each firm in the baseline equilibrium to compute short-run changes in experience returns immediately following export entry. As equation (11) shows, export entry leads to changes in the increment of human capital per time spent, changes in work time, and higher labor revenues that affect wage profiles by widening the scope of wage renegotiations. We discuss the details on computation in Appendix F.1.

To inform our choice of moments for the determination of parameters, we trace the dependence of certain parameters to specific moments. For example, export demand at destination $n$, $P_n^{\sigma} Y_n \tau_n^{1-\sigma}$, directly affects the share of sales to $n$ in firms' total sales, and the average export cost, $\bar{f}_n$, determines the share of firms that export to destination $n$. We infer the bargaining power $\beta$ mainly from the increase of workers' wages with firm size. A larger $\beta$ implies that workers obtain proportionally higher shares of the surplus at larger and more productive firms. The on-the-job search intensity $\eta$ relates to the share of new hires that were employed in other firms (last year).

Finally, for a given strength of wage renegotiations (mainly governed by the workers' bargaining power $\beta$ and the on-the-job search intensity $\eta$), average experience returns are informative of the magnitude of the human capital increment shifter $\mu$. The increase of experience returns with firm size and the change in experience returns due to export entry into high-income countries regulate the dependence of the human capital increment on firm productivity $\gamma_1$ and on the

destination-specific knowledge stocks $\gamma_2$, respectively.[22]

## IV.C Calibration Results

Table 2 presents the internally calibrated parameters in Panel B. Our parameter values are similar to those in the literature. For example, our calibrated job destruction rate and on-the-job search intensity are 0.16 and 0.12, respectively, and close to 0.15 and 0.11–0.16 found in Fajgelbaum (2020) for Argentine manufacturing firms. Our calibrated wage bargaining power $\beta = 0.6$ is comparable to estimates for bargaining models with wage renegotiation and human capital accumulation: Gregory (2021) estimates the bargaining power $\beta$ to be 0.66 at German employers, whereas Bagger et al. (2014) find $\beta$ to be between 0.29–0.32 at Danish firms. Appendix Table F.1 shows that our model closely matches the targeted moments. In Appendix F.2 we discuss untargeted moments in the calibrated model and their similarity to data moments, providing additional support for the applicability of the model. In particular, our model-generated differences in experience effects between exporters and non-exporters are similar to those in the data, and our model predicts negative changes in experience effects due to export entry into non-high-income countries in line with the reduced-form evidence in Appendix Table D.13.

## IV.D Decomposing the Returns to Experience

With the calibrated model, we now turn to understanding the factors that shape experience-wage profiles. In Appendix F.3, we show that human capital accumulation accounts for about 70% of workers' overall wage growth over the life cycle. There are diminishing returns to human capital investment, however, so human capital growth can only account for 55% of the difference in lifetime wage growth between exporters and non-exporters. We also find that human capital accounts for half of the gains in experience returns after export entry into high-income countries.

[22] There are no direct correspondences between $\{\gamma_1, \gamma_2\}$ and the data, so our estimation relies on indirect inference (Gouriéroux and Monfort, 1996). Appendix Table G.1 reports the Jacobian matrix showing how changes in $\gamma_1$ and $\gamma_2$ affect the moments and confirms that the slope of experience returns with respect to firm size is mostly responsive to $\gamma_1$ while the change in experience returns due to export entry into high-income countries is mostly responsive to $\gamma_2$.

# V Quantitative Evaluation

We now use our calibrated model to study the role of human capital formation in shaping the gains from trade and how this role depends on export destinations. We then provide robustness checks regarding model assumptions and parameters.

## V.A Gains from Trade

Table 3 reports the gains from trade in Panel A, computed in the calibrated model as the ratio of real consumption with trade to real consumption in autarky. For autarky, we set Brazil's bilateral trade costs with foreign economies to infinity. The overall gains from trade are 7.78%. More human capital and trade-induced real wage gains, resulting in higher real income per efficiency labor, both contribute to the gains from trade, with a 3.98% and 3.75% increase in real income, respectively. We allow for unemployment and show that trade openness increases firms' overall vacancy postings, which also leads to a 0.51% employment gain. With trade openness, workers and firms choose to set aside more time for human capital accumulation, so the average work time decreases by 0.46% after trade openness.

## V.B Export Destinations and Human Capital Formation

Our empirical evidence and model highlight the potential importance of export activity and especially export destinations in affecting human capital formation. To further understand this force quantitatively, we first provide a decomposition of the change in human capital growth after trade openness and then perform two additional counterfactual exercises.

**Table 3:** Gains from Trade

Panel A: Gains from Trade from Autarky to Calibrated Economy

| | | | |
|---|---|---|---|
| Changes in Real Income from Autarky to the Calibrated Economy | | | 7.78% |
| *Decomposition:* | | | |
| | Real Income Per Employee | | |
| Employment | Income Per Efficiency Labor | Human Capital | Working Time |
| 0.51% | 3.75% | 3.98% | -0.46% |

Panel B: Comparing Baseline Model to Model with Common Learning Returns

| | | | Gains from Trade | |
|---|---|---|---|---|
| | Increase of Experience Returns with Firm Size | ΔExperience Returns from Exports to High-income Dests | Real Income | Human Capital |
| (1) Data | 0.15 | 0.22 | | |
| (2) Baseline | 0.15 | 0.21 | 7.78% | 3.98% |
| (3) Common returns ($\gamma_1 = \gamma_2 = 0$) | -0.20 | -0.03 | 5.05% | 0.17% |

Panel C: Gains from 10% Decline in Variable Export Costs

| | Export / Output | GDPPC (Brazil=1) | 10% Decline in Trade Costs | |
|---|---|---|---|---|
| Export destinations | | | Δ%Real Income | Δ%Human Capital |
| *By income levels:* | | | | |
| High-income | 0.081 | 3.58 | 1.25% | 1.43% |
| Non-high-income | 0.053 | 1.10 | -0.13% | -0.75% |
| *By main export destinations:* | | | | |
| Euro area & United States | 0.070 | 3.60 | 0.81% | 1.17% |
| China (2019) | 0.069 | 1.19 | 0.12% | -0.72% |
| South America | 0.032 | 1.12 | -0.24% | -0.54% |

*Notes*: Panel A: Gains from trade computed in the calibrated model as the ratio of real consumption with trade to real consumption in autarky. Panel B: Comparison of (1) data moments to moments in both (2) calibrated baseline model and (3) alternative model with no firm- or export-specific learning returns ($\gamma_1 = \gamma_2 = 0$). For re-calibration of alternative model, we do not target the increase of experience returns with firm size and the change in experience returns due to export entry into high-income countries, which mainly discipline the parameters $\gamma_1$ and $\gamma_2$ (but results are similar if these two moments are being targeted). Panel C: Proportional changes in real income and human capital after a 10% decline in Brazil's variable export costs to different export destinations. See footnote 25 for details on the exercise regarding China.

### V.B.1 Decomposition of human capital growth

Appendix Figure G.1 compares the distribution of workers' human capital growth between autarky and trade openness in the calibrated economy, indicating faster human capital growth after trade integration. Motivated by common decompositions of productivity growth (see, e.g., Foster, Halti-

**Table 4:** Changes in Human Capital Growth

*Panel A: Changes in human capital growth from autarky to the calibrated economy*

| Overall | Between-firm Term | Within-firm Term | Cross-firm Term |
|---|---|---|---|
| 0.12% | 0.01% | 0.09% | 0.02% |

*Panel B: Within-firm term by firms' status in the calibrated economy*

| Non-exporters | Exporters (High-income) | Exporters (Non-high-income) | Exporters (Both Income Groups) |
|---|---|---|---|
| -0.03% | 0.08% | -0.02% | 0.06% |

*Notes*: Panel A reports decomposition of human capital growth according to equation (12). Panel B further decomposes within-firm term according to a firm's export status in calibrated economy.

wanger and Krizan, 2001), we decompose changes in human capital growth under trade openness to reflect the contributions of different forces. We denote the average per-period human capital growth in the economy with $g_h = \int \ell(\omega) g_h(\omega) \, \mathrm{d}\Phi(z(\omega))$, where $\ell(\omega)$ is firm $\omega$'s employment share, and $g_h(\omega)$ is average growth in human capital per period at firm $\omega$. The changes in the growth of human capital can thus be written as

$$g_h' - g_h = \int \underbrace{[\ell'(\omega) - \ell(\omega)][g_h(\omega) - g_h]}_{\text{between-firm term}} + \underbrace{\ell(\omega)[g_h'(\omega) - g_h(\omega)]}_{\text{within-firm term}} + \underbrace{[\ell'(\omega) - \ell(\omega)][g_h'(\omega) - g_h(\omega)]}_{\text{cross-firm term}} \, \mathrm{d}\Phi(z(\omega)). \tag{12}$$

The first term captures employment reallocation given the initial human capital growth, whereas the second term measures within-firm changes in human capital growth. The third term represents the cross effect of reallocation and changes in human capital growth.

Table 4 reports the decomposition results. The between-firm term contributes only slightly to the increase in human capital growth, reflecting the trade-induced labor reallocation toward more productive firms in a Melitz (2003) model. The within-firm term contributes the most to the increase in human capital growth. Panel B of Table 4 further decomposes the within-firm term according to a firm's export status in the calibrated economy. Consistent with relatively higher knowledge stocks at high-income destinations compared to Brazil, firms that solely export to high-income destinations contribute the most to the increase in human capital growth between autarky and the calibrated economy, followed by the importance of firms that export to both high-income and non-high-income destinations. Non-exporters and exporters that only sell to non-high-income

countries contribute negatively to the within-firm term.[23] This result confirms that high-income destinations are associated with increased human capital formation.

### V.B.2 Model with identical returns to firm learning

We now compare our baseline model to a model with neither firm-specific nor trade-specific human capital accumulation. Under the functional form of the human capital increment per time $\phi^E(\omega) = \mu z(\omega)^{\gamma_1} \left(\phi^O(\omega)\right)^{\gamma_2}$ in equation (6), $\gamma_1$ is the elasticity of the human capital increment to firm productivity and governs how the labor allocation between firms affects human capital accumulation. The parameter $\gamma_2$ is the elasticity of the human capital increment to destination-specific knowledge $\phi^O(\omega)$, shaping how entry into export destinations affects human capital formation. We now set $\gamma_1 = \gamma_2 = 0$ such that all firms have the same human capital increment, and learning-by-exporting is no different from general learning, and recalibrate this alternative model to the targeted data moments in Appendix Table F.1.

Table 3 reports the results in Panel B. This alternative model predicts that more productive firms and entry into high-income destinations are associated with negative changes in experience returns, which is inconsistent with the data. This is because higher revenues per labor (due to higher firm productivity or export-market participation) raise opportunity costs of human capital investment and lead to lower investment levels. In contrast, in the baseline model with $\gamma_1 > 0$ and $\gamma_2 > 0$, the human capital increment increases with firm productivity and destination-specific knowledge, offsetting the effects of opportunity costs. The contrasting results highlight the importance of modeling the dependence of the human capital increment on firm productivity and destination-specific knowledge to successfully match changes in experience returns across firms and after export entry. The gains in human capital from trade are negligible in the alternative model since trade does not directly affect the human capital increment.[24]

[23] Numerically, non-exporters and exporters that only sell to non-high-income countries only slightly change human capital investment after trade openness. However, their hires' average human capital is higher (due to general equilibrium effects) after trade openness, so the contribution of these firms to the human capital growth becomes smaller.

[24] In the alternative model, the slight gains in human capital from trade are partly due to the fact that trade openness encourages more job vacancies and reduces the duration of unemployment, which in turn facilitates human capital

### V.B.3 Trade liberalization with different destinations

Given the large differences in knowledge stocks across destinations, we explore how the effects of trade liberalization vary by destination. In the upper two rows of Panel C in Table 3, we compute changes in real income and human capital after a 10% decline in Brazil's variable trade costs to high-income and non-high-income destinations, respectively. Lowering trade costs to high-income destinations by 10% increases Brazil's real income by 1.25%, largely due to a 1.43% increase in workers' average human capital. The gains in human capital exceed the gains in real income, as firms export more to high-income markets to facilitate workers' human capital formation, which lowers revenues per labor. Surprisingly, lowering trade costs to non-high-income destinations by 10% reduces Brazil's real income by 0.13%. This reduction is mainly driven by a 0.75% decline in workers' average human capital, as higher demand from non-high-income destinations induces productive firms to allocate labor away from high-income export destinations. In addition, higher revenues per efficiency labor due to exporting increase the opportunity costs of investing in human capital. It is worth noting that our focus lies on steady-state comparisons (because of computationally intractable transitional dynamics). At impact, it is possible that lower variable trade costs to non-high-income destinations leads to short-run gains due to changes in wages and prices.

In the lower three rows of Table 3 (Panel C), we report changes in real income and human capital after a 10% decline in Brazil's variable trade costs to main export destinations.[25] In line with our previous results on high-income countries, lowering trade costs to Europe and the United States leads to large gains in real income, which are mainly driven by gains in workers' human capital. On the other hand, the wage and price gains from lowering trade costs to China or South America are largely offset by drops in human capital levels.

formation.

[25] Our baseline model is calibrated to the export data in 2000, when non-high-income countries in Asia (mainly China) were still a relatively small export destination for Brazil. Brazil's exports to China grew fast over the recent decades (Appendix A.1). In the counterfactual exercise regarding China, we first recalibrate the demand and the knowledge stock of non-high-income countries in Asia to match Brazil's export-to-output ratio to China and the relative GDP per capita between China and Brazil in 2019.

### V.C Robustness Checks

In Appendix F.4, we provide several robustness checks regarding the key parameters. We also consider an alternative way of modeling human capital accumulation through learning-by-doing. We find that across all these alternative specifications, human capital generally contributes to the gains from trade, with an increase in real consumption ranging from 2.13% to 6.90%.

## VI Conclusion

Using Brazilian administrative employer-employee and customs data, we document that workers' within-job life-cycle wage growth is faster at exporters than at non-exporters. Apart from selection of firms with higher returns to experience into exporting, we find that workers enjoy steeper experience-wage profiles when firms export to high-income destinations.

To interpret the data and conduct experiments, we develop and quantify a dynamic firm-level model with export-market entry, worker-firm wage bargaining, and workers' human capital accumulation. In the model, workers' within-job pay grows due to human capital growth, changes in the time allocated to working or learning, and wage renegotiations in response to poaching attempts. We consider the possibility that the human capital increment can depend on export destinations. We calibrate the model and find that human capital growth can explain roughly 50% of the differences in wage growth profiles between exporters and non-exporters as well as the gains in experience returns after entry into high-income destinations. Our calibrated model suggests that the increased human capital per worker accounts for one-half of the overall gains in real income from trade.

Trade affects workers' wages in multiple ways. Understanding the different mechanisms by which wages can move with trade is of crucial importance to assess aggregate welfare and inequality. This study takes a first step to empirically and quantitatively understand the effects of trade on workers' life-cycle wage growth. Our results indicate that workers' human capital accumulation may interact with export markets. A fruitful area for future study is how this interaction impacts

workers' income levels and inequality in countries with different development levels, which will ultimately lead to a better understanding of the welfare impact of globalization.

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