Escaping the Losses from Trade: The Impact of Heterogeneity and Skill Acquisition*

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Abstract

We study skill acquisition as a margin of adjustment to trade shocks. We exploit variation in import competition across U.S. regions to identify the effects of trade on skill acquisition decisions and labor market outcomes for adult workers. We provide evidence of increased college enrollment by young individuals located in regions more exposed to import competition. Yet, we show that this increase in enrollment is driven by individuals in wealthier households. Labor market opportunities for adult workers in more exposed regions deteriorate, and this worseninig is driven by the outcomes of workers without a college education. Guided by our empirical findings, we develop a multi-region model of international trade with costly skill acquisition decisions and endogenous wealth dynamics. Our model implies that skill acquisition is a key margin of adjustment in determining the long-run distributional welfare consequences of trade.

*The views in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of any other person associated with the Federal Reserve System.

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1 Introduction

Trade affects workers unevenly. By shifting economic activity across occupations, firms, industries, or regions, freer trade can generate gains for some workers and losses for others. The differential effects are evident for workers with different education levels. Freer trade has led to a decline in the income of workers without a college education relative to that of college-educated workers in many countries.[1] These distributional consequences generate incentives for workers to adjust over time. Most literature has focused on studying the margins of adjustment available to the current generation of workers, such as switching occupations, firms, industries, or regions in which they work. However, these works have mostly overlooked the margins of adjustment available to future generations of workers, such as skill acquisition.

In this paper, we study skill acquisition as a margin of adjustment to trade. Relying on cross-regional variation in import penetration across U.S. local labor markets (Autor et al., 2013), we establish two novel facts. First, we provide evidence of increased college enrollment by young individuals in regions more exposed to import competition. Second, we document that the increase in college enrollment depends on households' wealth, with the increase in aggregate enrollment mainly driven by individuals in wealthier households. In line with our first fact, we also document a deterioration of labor market outcomes for adult workers in more exposed regions that is largely driven by the outcomes of workers without a college education. Guided by our empirical findings, we develop a multi-region model of international trade with costly skill acquisition decisions, endogenous wealth dynamics, and reallocation frictions faced by workers that can move across sectors and regions. Our model implies that skill acquisition is a key margin of adjustment in determining the long-run distributional welfare consequences of trade.

To identify the effects of trade on college enrollment, we exploit variation in import competition across U.S. commuting zones generated by the rise of China in world trade markets (Autor et al., 2013). Using both the American Community Survey (ACS) and the Panel for Socioeconomic and Income Dynamics (PSID), we construct college enrollment measures based on the commuting zone where individuals were located before enrolling into college. Relying on the changes in import penetration provided by Autor et al. (2013), we estimate that a $1,000 increase in import penetration increases (i) the share of individuals ages 18 to 25 enrolled in college by close to 0.9 percentage point, and (ii) the likleihood of high school graduates enrolling into college by 5 percentage points. However, our data also show that the average increase in this likelihood is driven entirely by individuals in wealthier households. While young individuals in the top half of the wealth distribution increase their enrollment by approximately 6 percentage points, individuals in the bottom do not increase their enrollment.[2] Hence, our results suggest that college enrollment—for those who can afford it—is a relevant margin of adjustment to trade openness for future generations of workers.[3] Aiming

[1] Autor et al. (2016) and Kim and Vogel (2020) provide evidence of the unequal effects of trade openness on different groups of worker in the United States. Burstein et al. (2013) and Burstein et al. (2016); Burstein and Vogel (2017) focus on the effects of trade on the college wage premium.

[2] Our point estimate of the average increase using enrollment in the PSID data is 4.5 percentage points.

[3] Our results are in line with those of Adão et al. (2020) who show that skill-biased technological transitions are

at uncovering the mechanisms underlying the increase in enrollment, we also use ACS data to construct regional measures of labor market outcomes for workers ages 30 to 55, who are likely to be in their prime working age. In line with previous research, we find that greater import penetration deteriorates the average labor income of adult workers. (Autor et al., 2013; Kim and Vogel, 2020) However, this result masks substantial heterogeneity across workers with different levels of education. While a $1,000 increase in import penetration reduces labor income by 1.4 percent for workers without a college education, there is no effect for workers with a college education. We show that these heterogeneous effects on labor income across education levels are also present on employment outcomes. Intuitively, one would expect these heterogeneous effects of trade on labor market opportunities to influence college enrollment decisions by young individuals, as put forward similarly in Atkin (2016) for the case of Mexico.[4]

Motivated by our empirical findings, we propose a model to study the welfare effects of trade openness in the presence of skill acquisition. The model embeds an Aiyagari-Bewley-Huggett economy (Aiyagari, 1994) into a multi-regionl model of international trade. Our framework features a life-cycle structure for workers with costly skill acquisition at the beginning of life, endogenous wealth dynamics, and intervivos transfers. The economy consists of a small open economy (SOE) composed of multiple regions. Production of tradables occurs in two sectors–manufacturing and services–each using high-skill and low-skill workers as factors of production. We think of a region-sector pair as a local labor market, and incroporate mobility frictions by assuming that workers can switch across these markets after paying a cost in the spirit of (Caliendo et al., 2019). Thus, the model adds skill acquisition as a margin of adjustment available to workers at the beginning life–new workers–on top of labor-market switching–switching across sectors, regions or both–available to workers throughout their lives.

We calibrate the model to the United States in the early 1990s, before a period of rapid increase in trade. We split the U.S. into three large regions for our calibration: West, Midwest, and Northeast. Regions in the model differ depending on how exposed they are to import competition–as measured in our empirical exercises. In the particular, regions in our model with more workers engaged in manufacturing activities in 1990 are more exposed to import competition, as the bulk of the rise in U.S. imports after this year was driven by manufactured goods. Even though the model can in principle accomodate a greater number of regions, we choose to keep heterogeienity along this dimension limited, while allowing for finer heterogeneity along other dimensions like wealth. Furthermore, the calibration also targets nationwide cross-industry and cross-household differences, while keeping heterogeneity across regions to that considered in our empirical analysis. In terms of the college enrollment decisions bloc of the model, our calbration relies on recent work that paid detailed attention to incroporating the microeconomics of human capital acquisition into macroeconomic model (Abbott et al., 2019; Daruich, 2023). A key element of the calibration is that manufacturing is more intensive in low-skill workers than services (Cravino and Sotelo, 2017). This

accompanied by changes in workers' skill distribution mainly driven by changes across generations.

[4] Charles et al. (2015) follow a similar strategy and first focus on changes in labor market opportunities, to then identify the effects of housing booms and busts on education decisions.

fact implies that increases in trade, by leading to different degrees of expenditure switching across sectors, will have relevant implications for the determination of the college wage premium. We model an increase in trade-openness as a decline in the cost of importing foreign goods, and set such decline to match the change in U.S. imports of services and manufactures between 1990 and 2010.[5] The implied cost declines reflect the disproportionate increase in U.S. import of manufactures during this period.

The model can account for the effects of trade openness on labor markets that we estimate in the data. In line with extensive evidence, trade openness leads to a larger decline in labor income in the regions more exposed to import competition. Moreover, this effect is more pronounced for workers without a college education. In terms of the mechanism in the model, the large increase in imports of manufactures requires workers to reallocate from manufacturing to services. Given that manufacturing is more intensive in non-college workers, the reallocation is more pronounced for this type of workers, leading to a relative decline in the income of non-college workers. That is, the model leads to a trade-induced increase in the college wage-premium in all regions that is in line with the typical Stolper-Samuelson mechanism. Importantly, the increase in the college wage-premium, and therefore also in the relative income of high-skill workers, is larger in the more exposed regions, as we document in our empirical analysis. Even though our calibration mainly targets steady state moments and only incorporate heterogeneity to construct differences in exposure to trade across regions, the model does surprisingly well quantiatively in matching our estimated effects on labor income across regions.

In response to the higher return to college, new generations of workers enroll more into college, and especially so in the more exposed regions. The model predicts an increase of 0.5 percentage point in college enrollment nationwide after 10 years of the time of the shock. Moreover, the model can match suprisingly well the heterogeneity in the response of college enrollment across regions. In addition, the model implies that the increase in enrollment is driven entirely by newborns with their parents in the services sector rather than manufacturing. One particularly interesting outcome of the model is that the trade shock by itself actually leads to a decline in college enrollment the region least exposed to import competition. As in our estimates, higher enrollment in the model comes exclusively from newborns in the wealthier households. Thus, the model is in line with our empirical findings above, and delivers an hump-shaped pattern for changes in college enrollment across households' wealth distribution.

Trade openness leads to changes in welfare that depend households' locations, sectors, education, and wealth at the time of the shock. While households in more exposed regions can suffer losses from trade on impact, the differences across regions are not sizable. Similarly, differences across education types only lead to sizable differences in welfare effects for households in the manufacturing sector at the time of the shock. However, a household's sector plays a more determinant role in shaping heterogeneous welfare effects with those in the manufacturing sector taking basically all

[5]Given the structure of our model, the effect of this decline in import costs on foreign prices is equivalent to price declines generated by increasing producitvity abroad as considered in other paper.(Caliendo et al., 2019; Traiberman, 2018; Dix-Carneiro et al., 2023)

losses. One key aspect of our frmework is that it allows us to examine the welfare effects of trade across the wealth distribution, similarly to recent work.(Lyon and Waugh, 2019; Carroll and Hur, 2020, 2023)

The model predicts that endogenous skill-acquisition shapes the long-run distribution of welfare gains due to trade openness. We compare the welfare gains of our *endogenous education* benchmark model with an alternative *fixed education* model where education is costly but inherited from parents. In both models, we compute welfare immediately upon the announcement of freer trade (short-run effect), as well as after a full life-cycle (long-run effect). In the short-run, both models predict similar welfare changes: a 0.75 percent consumption equivalent gain for college workers, and a 0.25 percent loss for non-college workers. In the long-run, however, consumption equivalent differences almost disappear in the *endogenous education* model: with gains of 0.25 percent and 0.5 percent for college and non-college workers, respectively. Yet, the differences in welfare gains actually increases same over time in the *fixed education* model. We conclude that endogenous skill-acquisition is a key margin of adjustment when evaluating the effects of trade openness.

Related Literature This paper is related to multiple strands of literature in International Trade and Macroeconomics. First, the paper is related to the relatively scarce literature studying the effects of trade on skill acquisition from both theoretical (Findlay and Kierzkowski, 1983; Danziger, 2017; Ma et al., 2023) and empirical (Atkin, 2016; Greenland and Lopresti, 2016; Blanchard and Olney, 2017) perspectives. We contribute to this literature by providing novel evidence that import competition led to an increase in human capital accumulation in the form of greater college enrollment in the U.S. Moreoveor, we show that these effects differ across households with heterogeneous levels of wealth. In addition, we propose a new multi-region quantitative trade model with costly skill acquisition and endogenous wealth dynamics, and provide a detailed calibration that incorporates recent developments in the macroeocnomic and human capital accumulation literature (Adão et al., 2020; Daruich, 2023). Our methodology allows us to carry out serious welfare calculations.

This paper is also closely related to the recent and growing literature incorporationg the structure of heterogeneous-agents macro models into international trade and spatial models. Incroporating this framework into trade models has aimed mainly at better understanding the effects of trade shocks on labor markets and inequality (Lyon and Waugh, 2019, 2018; Carroll and Hur, 2020, 2023; Waugh, 2023), while for the case of spatial models, work has focused on studyin the interaction between wealth and reallocation across space (Greaney, 2020; Giannone et al., 2023; Dvorkin, 2023). We contribute to this strand of literature by focusing on endogenously determined skill levels in a life-cycle setting, while still allowing for other margins of adjustment like reallocation across sectors and space available to households to cope with trade shocks.

The paper also contributes to the literature on the effects of trade shocks on labor markets. (Autor et al., 2013; Pierce and Schott, 2016) Our empirical analysis is closely related to Autor et al. (2013) who provide evidence of the detrimental effects of import penetration shocks on earnings and employment. We contribute to this literature by providing evidence on the effects of import penetration shocks on college enrollment decisions that differ across households' wealth distribution.

In terms of modeling choices, this paper is closely related to the literature on structural trade models with labor market dynamics. (Artuç et al., 2010; Coçar et al., 2016; Dix-Carneiro, 2014; Caliendo et al., 2019) We contribute to this literature by bringing in the wealth heterogeneity dimension into models of labor market dynamics and showing that the initial distribution of wealth matters for how trade shocks affect workers heterogeneously. Hence, our paper also speaks to the broader literature on trade and inequality (Helpman et al., 2010, 2017; Burstein et al., 2013; Antràs et al., 2017).

Lastly, this paper also contributes to the quantitative literature on the effects of trade between different groups of workers (Kim and Vogel, 2020; Burstein et al., 2016; Burstein and Vogel, 2017). We contribute to this literature not only by examining changes in skill acquisition induced by the initial changes in the skill premium caused by lower trade costs, but also by adding the important dimension of wealth heterogeneity in order to understand the impact of trade.

Roadmap The rest of the paper is organized as follows. In Section 2 we conduct our empirical analysis and estimate the effects of trade shocks on college enrollment. In Section 3 we lay down the model and discuss its calibration. In Section 4 we carry out our quantitative exercises, and in Section 5 we discuss the welfare effects of endogenous skill acquisition. Section 6 concludes.

2 Import Competition and College Enrollment

Our empirical analysis exploits variation in exposure to trade across regions in the United States. In particular, we rely on the import penetration measure proposed by Autor et al. (2013) for U.S. commuting zones—which we also refer to as local labor markets. The fast expansion of China in the world economy starting in the early 1990s led to changes in this import penetration measure that differ across commuting zones. Hence, we exploit this variation to estimate the effects of trade on (i) adults' labor market outcomes with different education levels and (ii) college enrollment.

Our empirical analysis consists of two parts. First, we estimate the effect of changes in import penetration on adults' labor market outcomes of different education groups. We do this because, in principle, differential changes in education-specific labor market conditions should matter for skill acquisition decisions of high school graduates.[6] Moreover, estimating these effects allows us to contrast our results with those of Autor et al. (2013) and investigate any differences.

In the second part of our analysis, we estimate the direct effect of these shocks on college enrollment. To do this, we rely on two different types of data: (i) regional-level data—as in the first part of our empirical analysis—and (ii) individual-level data. Individual-level data allow us to analyze individual enrollment outcomes and their interaction with individual wealth levels. In this part of our analysis, the effect of the import penetration shock in isolation is still identified off of differences across local labor markets, but the identification of the interaction between trade shocks and individual income relies on within local labor market variation.

[6] Charles et al. (2015) follow a similar strategy to identify the effects of housing booms and busts on labor market opportunities and education decisions.

2.1 Import Penetration Measure

We consider commuting zones in the United States and denote them by r. These regions are characterized by strong commuting links within each region, but weak commuting links between regions. There are 722 commuting zones. For each of these zones, Autor et al. (2013) construct a measure of import penetration in a given time period t as follows:

$$\Delta IPW_{rt} = \sum_i \frac{L_{rit}}{L_{rt}} \frac{\Delta M_{it}}{L_{it}}, \tag{1}$$

where r denotes the commuting zone, i the industry, ΔM_{it} the change in Chinese imports into the United States in industry i between periods t and $t-1$, and L_{rit} the number of workers employed in that industry. Note that changes in imports are not only scaled by the number of workers employed in the corresponding industry, but they are also weighted by the share of total industry i workers working in region r, where $L_{rt} = \sum_i L_{rit}$ and $L_{it} = \sum_i L_{rit}$. The import penetration measure in equation (1) provides a proxy for trade shocks at the regional level. We follow Autor et al. (2013) and instrument U.S. imports from China by those of other high-income countries.[7]

We consider changes in import penetration over the two different time periods: 1990 to 2000 (1990-2000) and 2000 to 2007 (2000-2007). Constructed changes in import penetration for commuting zones have a median of $1,140 for 1990-2000 and $2,600 for 2000-2007, as well as inter-quartile ranges of $600 for 1990-2000 and $1,500 for 2000-2007.[8] Hence, import penetration across U.S. regions became more pronounced and dispersed after the year 2000.

2.2 Labor Market Outcomes

To estimate the effect of ΔIPW_{rt} on variable y_{rt} we consider the empirical specification

$$\Delta y_{rt} = \gamma_t + \beta \Delta IPW_{rt} + \delta X_{rt} + u_{rt} \tag{3}$$

where Δy_{rt} will denote either changes in labor income, employment or college enrollment. When we investigate how these effects vary across education groups we consider a set of group-specific controls, X_{rt}, that include labor force characteristics and regional dummies among others. We cluster residuals at the state level. To carry out our estimation we consider data from the American Community Survey (ACS) obtained through Integrated Public Use Microdata Series (IPUMS).

We focus first on specification (3) when Δy_{rt} is the change in income per capita of adults ages 30 to 55.[9] We focus on workers ages 30-55 because we believe labor market opportunities for these

[7] The actual instrument we consider for region r and period t is given by

$$\Delta IPW_{ort} = \sum_i \frac{L_{rit-1}}{L_{rt-1}} \frac{\Delta M_{oit}}{L_{it-1}}, \tag{2}$$

where M_{oit} are Chinese's imports from other advanced countries and we consider lagged values of employment.

[8] These quantities are all expressed in yearly changes.

[9] Table 1 is the equivalent to Table 3 in Autor et al. (2013), but with income of adults of ages 30-55 as the dependent variable, rather then employment by working age population.

workers are the ones considered as relevant by younger cohorts making education decisions. Table 1 presents our results when we include the different sets of control variables considered by Autor et al. (2013). The values in parentheses report standard errors.

Table 1: Imports from China and Change in Income per Capita for Workers Ages 30-55 within CZ, 1990-2007: 2SLS Estimates

Dependent variable: 10 × annual change in the log of income per adult ages 30-55 (in % pts)

	1990-2007 stacked first differences					
	(1)	(2)	(3)	(4)	(5)	(6)
(Δ imports from China to US)/ worker	-1.322*** (0.354)	-0.479 (0.418)	-0.628 (0.413)	-0.666* (0.374)	-0.865** (0.393)	-0.917** (0.391)
manufacturing share$_{-1}$		-0.275*** (0.081)	-0.252*** (0.061)	-0.195*** (0.066)	-0.195* (0.074)	-0.107 (0.074)
college share$_{-1}$				0.142** (0.070)		0.213** (0.097)
foreign born share$_{-1}$				-0.009 (0.035)		0.030 (0.041)
routine occupation share$_{-1}$					-0.560** (0.213)	-0.504** (0.200)
average offshorability$_{-1}$					3.422** (1.356)	0.602 (1.268)
Census division FE	No	No	Yes	Yes	Yes	Yes

Notes: N = 1,444 (722 CZs by two time periods). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; standard errors are clustered by state; the regression analyses are weighted by initial CZ share of national population. All control variables are the same as the baseline controls in Autor et al. (2013).

For the specification including all control variables considered by Autor et al. (2013) (column (6)), our estimates show that import penetration decreases labor income per person. More specifically, an increase in relative import penetration of $1,000 decreases labor income by approximately 1 percent. These results are in line with those in Autor et al. (2013).

While the effect of import penetration shocks on workers' average labor income is negative–as shown in Table 1–this result masks substantial heterogeneity in the effects of these shocks across individuals with different levels of education. Column (1) in Table 2 shows the estimates of β for subgroups of 30-55 year olds with different education levels when we include all controls considered in Table 1 (column (6)). Panel A of Table 2 considers the effects for individuals without any college education. Panel B presents the estimates for individuals with any college education: those with some college education, with a 2-year or a 4-year college degree. Column (1) shows that the negative effects of import shocks on labor income are concentrated among workers without a college education. A $1,000 increase in imports reduces the income of low-skill workers by 1.4 percent, while the same shock does not have a statistically significant effect on the income of high-skill workers. These results suggest that import penetration shocks increase the opportunity cost of not enrolling into college for new generations of workers.

Columns (2) and (3) of Table 2 report the estimates of the effects of import penetration shocks on total employment and on the share of workers employed in manufacturing. For the case of

Table 2: Imports from China and Labor Market Opportunities across Education Levels for Workers Ages 30-55 within CZ, 1990-2007: 2SLS Estimates

	1990-2007 stacked first differences		
	Income per Capita (1)	Employment per Capita (2)	Employment Share in Manufacturing (3)
Panel A			
High School or Less			
ΔIPW_{rt}	-1.365**	-1.062***	-0.520***
	(0.521)	(0.304)	(0.131)
High School			
ΔIPW_{rt}	-1.409***	-1.129***	-0.642***
	(0.449)	(0.306)	(0.142)
Panel B			
Some College			
ΔIPW_{rt}	-0.547	-0.466***	-0.422***
	(0.356)	(0.133)	(0.117)
2-year College Degree			
ΔIPW_{rt}	-0.445	-0.450**	-0.688***
	(0.639)	(0.180)	(0.148)
4-year College Degree			
ΔIPW_{rt}	-0.365	-0.308**	-0.277**
	(0.404)	(0.122)	(0.122)
Observations	1,444	1,444	1,444
Baseline Controls	Yes	Yes	Yes

Notes: Dependent variables denote 10 × annual change in (1) the log of income per person of adults ages 30-55, (2) the share of all adults ages 30-55 employed and (3) the share of adults ages 30-55 employed in manufacturing (in % pts); * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; standard errors are clustered by state; the regression analyses are weighted by initial CZ share of national population. All control variables are the same as the baseline controls in Autor et al. (2013).

total employment, column (2) shows that trade shocks reduce employment of all adult workers independently of their education level. However, the effects are more negative for workers without a college education. While a $1,000 greater import shock leads to a 0.47 percentage point decrease in employment of those individuals with some college education, the share of workers without any college education suffer a drop in employment twice as large (1.06 percentage points). Turning to the share of workers employed in manufacturing, column (3) shows a large decline in this share across all education levels. This last result implies that, independently of workers' education level, employment in the manufacturing sector shrunk relatively more in those commuting zones facing greater import penetration shocks.[10]

Our previous results provide evidence of a significant increase in the opportunity cost of not

[10] Autor et al. (2013) also find that and increase in import penetration (i) does not lead to migration across regions, (ii) leads to a modest decline in local non-manufacturing employment, (iii) leads to a sharp rise in labor force non-participants, and (iv) leads to employment reductions equally concentrated among young, mid-career and older workers, but employment losses are relatively more concentrated in manufacturing among the young and in non-manufacturing among the old.

going to college generated by higher imports. Hence, we would expect some future workers to choose to go to college in response to the deterioration of labor market opportunities for workers without some college education. Moreover, we would expect to witness a greater increase in enrollment by individuals in more exposed regions. In the following subsection we show that this is the case by estimating the effect of the import penetration shocks directly on college enrollment.[11]

2.3 College Enrollment

To estimate the effects of trade on skill acquisition we must first construct college enrollment measures. However, constructing these measures at the regional level poses important challenges. In particular, the fact that many individuals ages 18-25 migrate across regions to enroll into college represents an issue for our identification strategy.[12] Unfortunately, the ACS considers individuals who leave home to go to college as separate households; thus making it difficult to link these individuals to the regions where they were located before going to college. We propose two strategies to account for individuals' possibility to migrate.[13]

Our first strategy relies on data on the location of individuals one and five years before they are interviewed in the ACS. We construct two measures of enrollment at the commuting zone level by linking individuals to the previous region where they were located. For a given commuting zone, our first measure considers individuals ages 18-25 who were there a year ago and computes the share of them with at most one year of college finished. Our second measure considers individuals ages 18-25 who were located in a given region five years ago and computes the share of them enrolled in any year of college. Even though our first measure is better at controlling for migration, it can be restrictive for some commuting zones with a relatively small number of observations, making shares noisy. Our second measure is less subject to noise, but it does not control for migration perfectly. Hence, we will consider both measures to partially account for migration associated with college enrollment.

Our second strategy considers individual level data from the PSID. Given the longitudinal nature of these data, controlling for migration is not an issue because we can follow individuals over time. Moreover, these data allow us to identify the effects of trade openness on college enrollment across households' wealth distribution. We would expect college enrollment decisions to depend

[11] Charles et al. (2015) follow a similar strategy to show how housing booms and busts affected labor market opportunities and, therefore, college attendance in the United States during the 2000s. Focusing on the case of changes in education induced by international trade, Atkin (2016) shows that the growth of export manufacturing in Mexico altered the distribution of education. The empirical strategy by Atkin (2016) can be thought of as skipping the step of constructing measures of export expansion, and instead taking a measure of changes in export employment directly as the independent variable.

[12] According to the Eagan et al. (2016), 48.4 percent of college freshmen in 1990 enrolled in colleges over 100 miles away from their permanent home. This number remained relatively stable over time and was 50 percent in 2015. Greenland et al. (2019) show that import penetration shocks have a statistically significant effect on migration of 15-34 year olds.

[13] Greenland and Lopresti (2016) also examine the effects of import penetration on education decisions. However, they focus on the case of high school graduation rates. Given that the vast majority of hight school students still live with their parents, they do not tend to migrate across regions. Hence, Greenland and Lopresti (2016) do not face the challenge posed by migration for identification.

on households' wealth to the extent that going to college is costly and there are imperfect credit markets.[14] Hence, we use individual level data on college enrollment and household wealth, and use the PSID confidential geocode data to merge these data with other regions-specific variable computed using ACS data. The PSID does not directly ask for college enrollment but contains information on years of school completed. We follow Lovenheim (2011) and measure enrollment as having completed more than 12 years of schooling.

We focus first on results following our first strategy. We consider the case in which Δy_{rt} in (3) denotes changes in college enrollment. Table 3 presents the results for our two measures of college enrollment constructed using ACS data. We control for the same set of variables that are included in column (6) of Table 1.

Table 3: Imports from China and College Enrollment for Individuals Ages 18-25 within CZ, 1990-2007: 2SLS Estimates

Dependent variable: 10 × annual change in the fraction of adults ages 18-25 enrolled

	1990-2007 stacked first differences			
	In current period t		In future period $t+1$	
	Enrolled in 1^{st}-Year College (1)	Enrolled in College (2)	Enrolled in 1^{st}-Year College (3)	Enrolled in College (4)
Adults ages 18-25				
ΔIPW_{rt}	0.187**	0.878***	0.355*	1.304***
	(0.086)	(0.192)	(0.201)	(0.396)
Observations	1,444	1,444	722	722
Baseline Controls	Yes	Yes	Yes	Yes

Notes: Dependent variables denote 10 × annual change in the fraction of adults ages 30-55 enrolled in some year of college [columns (1) and (3)] and the fraction of adults ages 18-25 enrolled in their first years of college [columns (3) and (4)] (in % pts); columns (3) and (4) consider lead dependent variables; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; standard errors are clustered by state; the regression analyses are weighted by initial CZ share of national population. All control variables are the same as the baseline controls in Autor et al. (2013).

Table 3 shows that greater import penetration leads to an increase in college enrollment for the two measures proposed. According to our estimates in columns (1) and (2), the effect of import penetration shocks on college enrollment should be between 19 and 90 basis points depending on the measure of enrollment that we consider. In particular, estimates in column (2) imply that a $1,000 increase in import penetration increases the fraction of individuals ages 18 to 25 enrolled in any year of college by 90 basis points. To put this number into perspective, the median 10-year change in this measure of enrollment for 1990-2007 was 280 basis points.Hence, a difference of 90 basis points across regions is sizable relative to the median change in enrollment. This evidence suggests that trade shocks have significant and sizable effects on education decisions in the United States.[15]

Columns (3) and (4) of Table 3 consider future changes in enrollment as the dependent variable.

[14] See Lochner and Monge-Naranjo (2012) and Solis (2017) for evidence on the relevance of wealth and access to credit for college enrollment decisions.

[15] text

To the extent that adjusting education decisions takes time, future enrollment should change in response to past trade shocks rather than more recent ones. The data points in the direction of a strong and sizable effect of increases in import penetration on future college enrollment. We can think of a story in which households slowly learn about aggregate labor market conditions. This sluggishness would imply that it takes time to internalize the increase in the payoff of a college education.

We turn now to our second strategy and examine individual level data from the PSID. At the individual level, we restrict attention to those who graduated high school in period t, and consider the following linear probability model:

$$e_{nrt} = \sum_q \beta^q \mathbb{I}_{\left\{Y_{h(n)rt} \in q\right\}} \Delta IPW_{rt} + \theta_Y Y_{h(n)rt} + \theta_e e^p_{h(n)rt} + \delta X_{rt} + u_{nrt} \tag{4}$$

where e_{nrt} denotes a dummy equal to one if individual n is enrolled in college after two years of graduating from high school in period t, and $\mathbb{I}_{\left\{Y_{h(n)rt} \in q\right\}}$ denotes an indicator function equal to one whenever individual n's household wealth is in quartile q, $Y_{h(n)rt} \in q$ where $q \in \{0\text{-}25, 25\text{-}50, 50\text{-}75, 75\text{-}100\}$. At the individual level, we control for the level of household wealth, $Y_{h(n)rt}$, and the level of education of the household head, where $e^p_{h(n)rt}$ is equal to one if the household head attended college. These two variables allow us to partially control for differences in the ability of high school graduates that are driven by wealth and education of the family. Our region-specific controls, X_{rt}, include lagged shares of (i) employment in manufacturing and of (ii) workers with a college degree. We also include time and region fixed effects in our regression.

Table 4: Imports from China and College Enrollment across Wealth Quartiles, 1990-2007: 2SLS Estimates

Dependent variable: Enrolled in college after two years of high school completion

	1990-2000 and 2000-2007 differences				
	Average	Quartile 1: $q = (0, 0.25)$	Quartile 2: $q = (0, 0.25)$	Quartile 3: $q = (0, 0.25)$	Quartile 4: $q = (0, 0.25)$
	(1)	(2)	(3)	(4)	(5)
ΔIPW_{rt}	0.045**	-0.003	0.050**	0.076**	0.048**
	(0.023)	(0.020)	(0.021)	(0.030)	(0.021)

Notes: Number of observations: 3,696. Dependent variables is a dummy equal to one if an individual of age 18-19 is enrolled in college after two years of graduating from high school in period t. Column (1) considers the average effect of changes in import penetration (no differences across wealth quartiles); columns (2) to (4) show the effects for individuals in different quartiles of the wealth distribution; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; standard errors are clustered by state; the regression analyses are weighted by initial CZ share of national population. Control variables include time fixed effects, region fixed effects, and lagged shares of employment in manufatruing and of workers with a college degree in region r.

Table 4 presents the results of our estimation. Column (1) shows our estimate of the average effect of changes in import penetration on college enrollment, that is, when we do not allow the coefficients of interest, β^q, to differ across the wealth distribution. In line with our previous results, an increase in import penetration leads to an increase in college enrollment. In particular, a $1,000

Figure 1: Imports from China and College Enrollment Across Income Quartiles

Notes: Values on the x-axis denote different quartile ranges. Blue points denote point estimates of β^q and red dashed intervals denote 95% confidence intervals. Number of observations: 3,696. Dependent variables is a dummy equal to one if an individual of age 18-19 is enrolled in college after two years of graduating from high school in period; standard errors are clustered by state; the regression analyses are weighted by initial CZ share of national population. Control variables include time fixed effects, region fixed effects, and lagged shares of employment in manufatruing and of workers with a college degree in region r.

increase in import penetration increases the probability of a high school graduate going to college by 5 percentage points. This is a sizable increase. Columns (2) to (5) present the estimates across wealth quartiles. For ease of exposition, we also plot these estimates in Figure 1. The figure shows that the increase in enrollment is driven by high school graduates living in the richest households. In particular, those living in households in the poorest quartile do not increase college enrollment at all. Moreover, our estimated coefficients follow hump-shaped pattern, suggesting that the strongest effects of import penetration on college enrollment are for individuals in households in the middle of the wealth distribution.[16]

In summary, our empirical results provide evidence of a deterioration of labor market outcomes for adult workers in the United States is largely driven by the outcomes of those without a college education. In line with these results, we show that college enrollment by young individuals increases in more exposed regions. Yet, this increase in enrollment is mainly driven by individuals in wealthier households. Guided these findings, we develop a model of international trade with costly skill acquisition decisions and endogenous wealth dynamics in the next section.

[16]We have estimated similar regressions with CPS data and using household income as a proxy for wealth. We find similar results and the hump shape persists. See Appendix B.

3 The Model

We consider a small open economy (SOE) composed of multiple regions indexed by $r \in \mathcal{R}$. Time is discrete, infinite, and indexed by $t = 0, 1, 2, \ldots$. The SOE is inhabited by a continuum of finitely-lived workers who live for J_R periods, have different education levels, and produce offspring at age $J_k < J_R$. Production in each region r is performed in two sectors—manufacturing and services—indexed by $i \in \{\mathbf{s}, \mathbf{m}\}$. Within each sector, intermediate goods are produced with labor, and the final good is produced with (domestic and foreign) intermediate goods.

At the beginning of their lives, workers decide whether to go to college or not. Going to college is a one-time costly irreversible investment. We refer to *college* workers as those who made the education investment, and *non-college* workers to those who didn't. After the education stage, workers enter the labor market. A labor market m is given by the region and industry pair $m = (r, i)$. At the end of each period, workers can choose to switch from one labor market to another, subject to a random utility cost. Newborns start in the same regions as their parents, but they can also decide to move. Thus, the model features three margins of adjustments for workers: endogenous skills acquisitions, regional migration, and industry switching.

While in the labor market, workers are exposed to idiosyncratic labor productivity shocks, but they can only self insure by saving/borrowing in one-period bonds subject to a borrowing limit. We assume this bond is the only financial asset workers have access to. Borrowing and saving happens in international financial markets, at an interest rate r^*, which the SOE takes as given.

In each region r, production in sector i is performed by intermediate good producers and final good producers. Intermediate goods are produced with *college* and *non-college* workers, and can be traded across countries and regions subject to iceberg-type trade barriers. Final goods are non-tradable and produced by combining domestic intermediate goods from all regions, as well as imported intermediate goods. The SOE assumption implies that imported intermediate goods can be purchased at exogenously given world prices. We also assume an exogenously given foreign demand for domestic exports.

We start by discussing firms in the economy and then move to workers. Since our focus is on perfect-foresight transitional dynamics, we describe the economy in a generic period t. We will first consider the economy in a stationary state, and then study the transition dynamics given an increase in trade openness in Section 4.

3.1 Firms

Intermediate Goods Producers.—The intermediate good in region r, in sector $i \in \{s, m\}$, at time t is produced by combining labor according to the technology

$$Y_{rit} = Z_{rit} \left(\gamma_i L_{crit}^{\frac{\sigma_i - 1}{\sigma_i}} + (1 - \gamma_i) L_{nrit}^{\frac{\sigma_i - 1}{\sigma_i}} \right)^{\frac{\sigma_i}{\sigma_i - 1}}, \tag{5}$$

where L_{crit} is *college* labor and L_{nrit} is *non-college* labor.

There are two important features—across sectors and regions—about the production technology that are worth highlighting. First, across sectors, we will assume that manufacturing is more intensive in *non-college* workers than services. That is, we assume $\gamma_s > \gamma_m$ for all regions r. Consequently, in line with Heckscher-Ohlin (HO) models of trade, an increase (decrease) in the relative price of intermediate services (manufactures) will increase the relative demand for *college* versus *non-college* workers, and thus the wage premium. Second, we assume that sectoral productivity may vary across regions, as captured by productivity Z_{rit}. Regional heterogeneity in productivity Z_{rit} implies different initial sectoral specialization across regions, and thus different exposure to trade openness.

Intermediate goods firms' profit maximization reads

$$\max_{L_{crit}, L_{nrit}} \{p_{rit} Y_{rit} - w_{crit} L_{crit} - w_{nrit} L_{nrit}\} \tag{6}$$
$$\text{subject to (5)}$$

where p_{rit} is the price of the tradable good in sector i, region r, at period t, and w_{crit} and w_{nrit} stand for *college* and *non-college* wages, respectively. Notice that the wages of *college*/*non-college* workers may not equalize across sectors since workers are not fully mobile.

Solving problem (5) we obtain the optimality condition

$$\frac{w_{crit}}{w_{nrit}} = \frac{\gamma_i}{1-\gamma_i} \left(\frac{L_{crit}}{L_{nrit}} \right)^{-\frac{1}{\sigma}}. \tag{7}$$

Equation (7) shows that the wage premium in a given region and sector —w_{crit}/w_{nrit}— is not simply determined by the relative aggregate supply of skills in that region. The allocation of aggregate skills across sectors within the region also matters for the determination of the skill premium, and this allocation will depend on comparative advantage, the world prices of tradable goods and sectoral productivity differences.[17]

Final Goods Producers.—The final good in region r is produced by combining intermediate goods from each region, as well as imported ones. For each sector $i = \{s, m\}$ and region r, final good producers aggregate intermediate goods using a nested Armington structure given by

$$Q_{rit} = \left[\omega_i^{\frac{1}{\eta_i}} D_{rit}^{\frac{\eta_i - 1}{\eta_i}} + (1-\omega_i)^{\frac{1}{\eta_i}} \left(D^*_{rit}\right)^{\frac{\eta_i - 1}{\eta_i}} \right]^{\frac{\eta_i}{\eta_i - 1}} \tag{8}$$

where D^*_{rit} is the imported intermediate good, and D_{rit} is an Armington aggregate combining domestic goods from all regions as

$$D_{rit} = \left(\sum_{\tilde{r} \in \mathcal{R}} \alpha_{ri\tilde{r}}^{\frac{1}{\theta_i}} \mathcal{Y}_{ri\tilde{r}t}^{\frac{\theta_i - 1}{\theta_i}} \right)^{\frac{\theta_i}{\theta_i - 1}}, \tag{9}$$

[17] Skill-biased technical change can easily be incorporated into this framework. We abstract from this feature in order to focus on the effects of trade openness on skill acquisition.

where $\mathcal{Y}_{ir\tilde{r}t}$ denotes the amount of intermediate goods demanded by sector i in region r from region $\tilde{r}$ in period t. We assume that shipping goods across regions and internationally is costly.

In equation (8), η_i denotes the elasticity of substitution between domestic and imported inputs, and ω_i is a shifter affecting sector-specific home-bias in trade. We allow both the trade elasticity, η_i, and home-bias shifters to vary across sectors. Analogously for equation (9), θ_i denotes the elasticity of substitution across domestic intermediate goods from different regions, and $\alpha_{ri\tilde{r}}$ is the demand shifter in region r towards goods produced in region $\tilde{r}$. This model structure nests multiple models in the literature depending on the parameter choices. For instance, if $\alpha_{ri\tilde{r}} = 0 \ \forall \tilde{r} \neq r$, then there is no trade across regions and the model boils down to an "island model" in which, given the supply of the types of labor, each region ("island") can be analyzed in isolation. In addition, if we assume that $\eta_i \to \infty$, then we obtain the standard SOE-HO model with two sectors.

The profit maximization problem of the final good producer reads

$$\max_{\{\mathcal{Y}_{ri\tilde{r}t}\}_{\tilde{r}\in\mathcal{R}}, D^*_{rit}} \left\{ q_{rit}Q_{rit} - \sum_{\tilde{r}\in\mathcal{R}} \tau_{ri\tilde{r}t} p_{\tilde{r}it} \mathcal{Y}_{ri\tilde{r}t} - \tau^*_{rit} p^*_{it} D^*_{rit} \right\} \tag{10}$$

subject to (8)-(9)

where q_{rit} is the price of the final good bundle Q_{rit} in region r, $\tau_{ri\tilde{r}t} \geq 1$ is the iceberg cost of moving goods from region $\tilde{r}$ to r, and τ^*_{rit} is the cost of importing the good to region r.[18] Notice that we allow iceberg-type costs to vary over time, thus generating changes in trade openness.

3.2 Workers

There is a continuum of finitely-lived worker of ages $j = 1, \ldots, J_R$. Workers derive utility from consuming a bundle $c = \mathcal{C}(c_s, c_m)$ composed of the final good of services, c_s, and manufactures, c_m. Each worker is endowed with $\bar{h}$ hours. Their labor productivity x evolves stochastically according to a Markov process with transition probabilities given by $\Pi_x(x', x)$. Workers can only save in risk-free bonds denominated in units of the final consumption bundle and with returns determined in world financial markets. At age J_k, agents become parents. We assume workers care about their offspring and allow for *intervivos* transfers.

We consider a dynastic framework with three main stages: pre-education, education, and a working stage. During the pre-education stage, newborns choose their education—to attend college or not—and a region-sector pair—a labor market—for their education stage. During the pre-education stage, agents are subject to idiosyncratic education- and region-sector-specific taste shocks that affect their education and location decisions. Furthermore, attending college and switching locations are both costly decisions. During their working stage, workers can swith labor markets at the end of every period, subject to a random taste shock. Next, we describe a worker's problem at the different stages of their life-cycle.

Working stage.—Let $V^j_t(a, x, r, i, e)$ be the maximum attainable life-time utility by an agent of

[18] Notice that we allow for iceberg-type trade barrier across regions in line with the literature on spatial economics.

age j, at time t, holding a units of the risk-free bond, with productivity x, working in sector i, with a level of education $e \in \{c, n\}$, and living in region r. During the working stage, the value is given as

$$\begin{aligned} V_t^j(a,x,r,i,e,j) &= \max_{c_s,c_m,a'} \left\{ U(c) + \mathbb{E}\left[\max_{m'} \left\{ \epsilon_{m'} - \psi_{je}(m,m') + \beta V_{t+1}^{j+1}(a',x',r',i',e) \right\} |x \right] \right\} \quad (11) \\ q_{rst}c_s &+ q_{rmt}c_m + q_{rt}a' \leq w_{riet}x\bar{h} + R^* q_{rt}a, \\ a' &\geq \underline{a}_{je} \end{aligned}$$

where $q_{rt} \equiv \mathcal{Q}(q_{srt}, q_{mrt})$ is the ideal price index of the consumption basket.

Workers face idiosyncratic labor-market specific taste shocks $\epsilon_{m'}$, which are realized at the end of period t after the agent has made consumption and saving decisions. At this point, workers can decide to move from labor market $m = (r, i)$ to $m' = (r', i')$, but they face an cost of switching $\psi_{je}(m, m')$. We assume that the taste shocks are *iid* across time and workers, and follow a Gumbel distribution $\epsilon_{m'} \sim Gumbel\,(-\rho_{je}\gamma, \rho_{je})$. Both, the cost of switching and the distribution of the taste shock, are potentially age-and-education specific. Notice that, unlike the region r and industry the i, the education level e does not change during the working stage. Finally, the borrowing limit $\underline{a}_{je}$ does not vary across labor markets, but is also age-and-education specific because of college loans, as we explain next.

Education stage.— College takes the first two periods of life, ages $j = 1, 2$. The cost of college per period in region r is denominated in terms of services and given by κ_r. Education also requires time, and workers can only work part-time while attending college. Workers can borrow to pay for college, and they can take time to repay the loan after graduating. If a newborn chooses not to go to college, they start their life in the working stage.

For ages $j = 1, 2$, the value for a newborn who attends college ($e = c$) in region r is given by

$$\begin{aligned} V_t^j(a,x,r,i,c) &= \max_{c_s,c_m,a'} \left\{ U(c) + \mathbb{E}\left[\max_{m'} \left\{ \epsilon_{m'} - \psi_{je}(m,m') + \beta V_{t+1}^{j+1}(a',x',r',i',c) \right\} |x \right] \right\} \quad (12) \\ q_{rst}c_s + q_{rmt}c_m &+ q_{rt}a' + q_{rst}\kappa_r \leq w_{rint}x\frac{\bar{h}}{2} + R^* q_{rt}a \\ a' &\geq \underline{a}_{jc} \end{aligned}$$

Thus, except for the cost of college and the reduced working hours, the education stage is similar to the working stage. Indeed, as in the working stage, we assume that workers can move across regions and industries, subject to a utility cost, during their education stage.

Pre-education stage.—At age $j = 0$, newborns choose their education level and the initial labor market. In particular, a newborn starts in their parent's region, observes parents' productivity and education, and receives a transfer from their parents. After receiving the transfer, newborns make their education decision. At this point, newborns don't know their initial productivity, but only that it correlates with their parents' productivity and education. Finally, at the end of age $j = 0$, idiosyncratic taste shocks are realized and newborns choose the labor market—a region-sector

pair—where they will go to school and work at age $j = 1$. The initial idiosyncratic labor productivity is realized at the very beginning of age $j = 1$.

Let's start with the newborn decision at the end of age $j = 0$, after they made an education decision e. At this point, the newborn chooses a labor market m where to start their life. Let $V_t^{0^+}(a, x_p, r_p, e)$ be the maximum attainable life-time utility if born in region r_p (p for parents), who received transfer a, with parents' productivity x_p and sector i_p respectively. Then

$$V_t^{0^+}(a, x_p, r_p, i_p, e) = \mathbb{E}_{\epsilon_m}\left[\max_m \left\{\epsilon_m - \psi_{0e}(m_p, m) + \mathbb{E}_x\left[V_t^1(a, x, r, i, e)|x_p\right]\right\}\right] \tag{13}$$

where ϵ_m is the idiosyncratic labor market-specific shock that is realized at the end of age $j = 0$ and $\psi_{0e}(m_p, m)$ is the education-specific cost of switching moving from parents' labor market. The newborn idiosyncratic productivity x has not yet been realized but it's distribution depends on the parents' productivity x_p.

Let's now move one step back to the education choice. At the beginning of age $j = 0$, the value of a newborn in region r_p, who received transfer a, and with parent's productivity x_p, sector i_p, and education e_p, is given as

$$V_t^{0^-}(a, x_p, r_p, i_p, e_p) = \mathbb{E}_\phi\left[\max\left\{V_t^{0^+}(a, x_p, r_p, i_p, c) - \phi, V_t^{0^+}(a, x_p, r_p, i_p, n)\right\}\right] \tag{14}$$

where ϕ is a random utility cost of going to college, which distribution depends on the parents' education e_p.

The optimal education policy e is obtained from solving (14) and the initial labor market choice $m = (r, i)$ is obtained from (13), which determines the measure $\mu_t^1(r, i, e)$ of workers age $j = 1$ in region r, industry i, and education e at time t.

Intervivos *transfers.*—At age J_k, workers choose the transfers to their newborns. The amount Φ to be transferred is given as

$$\max_{\Phi \geq 0}\left\{V_t^{J_k}(a - \Phi, x_p, r_p, i_p, e_p) + \hat{\lambda} V_t^{0^-}(\Phi, x_p, r_p, i_p, e_p)\right\} \tag{15}$$

where $\hat{\lambda}$ is how much parents discount their newborns' utility.

For ages $j \geq 1$, let $\mathbf{c}_{\mathbf{s}t}^j(a, x, r, i, e)$, $\mathbf{c}_{\mathbf{m}t}^j(a, x, r, i, e)$, and $\mathbf{a}'^j_t(a, x, r, i, e)$ denote the workers' optimal policies for consumption of services, manufactures, and saving, respectively; and by $\mathbf{m}'^j_t(a, x, r, i, e, m')$, the probability of switching from labor market m to labor market m' at the end of period t. For age $j = 0$, let $\mathbf{m}_t^0(a, x_p, r_p, i_p, e, m)$ denote the probability that a newborn chooses labor market m, and $\mathbf{e}_t^0(a, x_p, r_p, i_p, e_p, e)$ denote the probabilities that a newborn chooses education e. We use these next to formally define an equilibrium.

3.3 Market Clearing and Equilibrium Definition

Next, we use workers' policies to describe aggregate demands, market clearing, and international flows of debt and goods.

Let $\mathcal{A}$ be the space of asset levels and $\mathcal{X}$ the space of productivities. Define the state $\mathcal{S} = \mathcal{A} \times \mathcal{X}$ and $\mathcal{B}$ the Borel σ-algebra induced by $\mathcal{S}$.

Measure.—Let $\mu_t^j(a, x, r, i, e)$ be the measure of agents age j, in region r, in period t, with foreign holdings a, productivity x and education level e, working in sector i. We normalize the measure to unity: $\sum_r \sum_{j=1}^{J_R} \sum_{i,e} \int_{\mathcal{B}} d\mu_t^j(a, x, r, i, e) = 1$ for all t. For later computations, denote by $\mu_t^{0^-}(r) = \sum_{i,e} \int_{\mathcal{B}} d\mu_t^{J_k}(a, x, r, i, e)$ the measure of newborns in region r *before* the education and labor-market decisions.

Labor Market.—Let L_{riet} be the intermediate good producers labor demand, in region r and sector i, of workers with education e. The labor market must clear for each type of labor e in each region separately. That is,

$$L_{rint} = \int x \frac{\bar{h}}{2} d\mu_t^1(a, x, r, i, c) + \sum_{j=2}^{J_R} \int x \bar{h} d\mu_t^j(a, x, r, i, n) \qquad \forall r, i, t \tag{16}$$

$$L_{rict} = \sum_{j=3}^{J_R} \int x \bar{h} d\mu_t^j(a, x, r, i, c) \qquad \forall r, i, t \tag{17}$$

where (16) takes into account that, while in college, workers supply labor part-time in non-college labor market.

Final Non-Tradable Goods.— Let $C_{rit} = \sum_{j=1}^{J_R} \sum_{i,e} \int \mathbf{c}_{it}^j d\mu_t^k(a, x, r, i, e)$ be aggregate consumption of the final good $i \in \{s, m\}$ in region r. The final good market must clear for each sector i and region r. That is

$$Q_{rst} = C_{rst} + \bar{\kappa}_{rt} \qquad \forall k, t \tag{18}$$

$$Q_{rmt} = C_{rmt} \qquad \forall k, t \tag{19}$$

where $\bar{\kappa}_{rt} = \int \kappa_r \mathbf{e}_t^0(\Phi, x_p, r_p, i_p, e_p) d\mu_t^{J_k}(a_p, x_p, r_p, i_p, e_p)$ denotes total services demanded for education investment, for $\Phi = \Phi(a_p, x_p, r_p, i_p, e_p p)$ the optimal *itervivos* transfer.

Intermediate Tradable Goods.— The tradable domestic good is demanded by final goods producers and by foreign firms. We assume an iso-elastic demand function for foreign demand of goods produced in each region r, $B_{rit}^* = \bar{B}_{it}^* (p_{rit})^{-\eta^*}$. The term $\bar{B}_{it}^*$ incorporates multiple factors that could shift the demand for intermediate goods produced domestically. For instance, this term incorporates the effects of iceberg-type trade costs that foreigners pay to purchase goods produced at home. Market clearing for tradable goods then implies

$$Y_{rit} = \sum_{\tilde{l}} \tau_{\tilde{r}irt} \mathcal{Y}_{\tilde{r}irt} + B_{rit}^* \tag{20}$$

where $\mathcal{Y}_{\tilde{r}irt}$ is given bt (10).

Agents' budget constraints together with market clearing conditions deliver a flow of funds condition describing the evolution of aggregate asset holding in each region, as well as nationally. Let $A_{rt+1} = \sum_{j,i,e} \int \mathbf{a}_t'^j(a, x, r, i, e) d\mu_t^j(a, x, r, i, e)$ be the total savings in region r. Then, aggregate

asset holdings of agents in region r evolve according to

$$\begin{aligned} A_{rt+1} - A_{rt} &= (R^* - 1)A_{rt} \\ &+ \sum_i \sum_{\tilde{r} \neq r} (\tau_{\tilde{r}irt} p_{rit} \mathcal{Y}_{\tilde{r}irt} - \tau_{ri\tilde{r}t} p_{\tilde{r}it} \mathcal{Y}_{ri\tilde{r}t}) \\ &+ \sum_i (p_{rit} B^*_{rit} - \tau^*_{rit} p^*_{it} D^*_{rit}). \end{aligned} \tag{21}$$

Equation (21) shows that a region can accumulate assets because of three reasons: the first line is accumulation due to return on previous savings; the second line implies an accumulation if the value of goods sold to other regions ($\sum_i \sum_{\tilde{r} \neq r} \tau_{\tilde{r}irt} p_{rit} \mathcal{Y}_{\tilde{r}irt}$) is larger than the cost of purchased goods from other regions ($\sum_i \sum_{\tilde{r} \neq r} \tau_{ri\tilde{r}t} p_{\tilde{r}it} \mathcal{Y}_{ri\tilde{r}t}$); and the third line implies an accumulation because of trade with foreigners.

Notice that $\sum_r \sum_i \sum_{\tilde{r} \neq r} (\tau_{\tilde{r}irt} p_{rit} \mathcal{Y}_{\tilde{r}irt} - \tau_{ri\tilde{r}t} p_{\tilde{r}it} \mathcal{Y}_{ri\tilde{r}t}) = 0$. Hence, the economy wide evolution of asset holdings is given by

$$A_{t+1} - A_t = (R^* - 1)A_t + \sum_r \sum_i (p_{rt} B^*_{rit} - \tau^*_{rit} p^*_{it} D^*_{rit}), \tag{22}$$

where $A_t = \sum_r A_{rt}$. Equation (22) is the standard current account identity: foreign assets accumulation in a country is the return on previous assets plus net exports.

3.4 Calibration

For our calibration, we split the U.S. into three large regions: West, Midwest, and Northeast. We rely on the Census classification of divisions to construct the three regions. We allow for both trade an mobility across these regions. For each of these regions, we compute total employment in 1990 and split it between services and manufacturing. The share of total employment in manufacturing by region implies that the most exposed region to import competition accroding to our import penetration measure is the Midwest, followed by the Northeast, and then the West. To generate the differences in initial exposure across regions we rely entirely on differences in sectoral productivity in the model, z_{ri}.

Trade openness in the model is then determined by the iceberg cost of importing goods τ^*_{it}. We consider a period of trade liberalization as a decline inτ^*_{it}. We start the economy at a steady-state with a high τ^*_i calibrated to observed trade flows in 1990, and analyze the effect of an (unexpected) drop in τ^*_i leading to trade flows observed around the year 2010. We refer to the high-τ^*_i steady-state as a "closed economy", and the low-τ^*_i steady-state as the "open economy".

We calibrate most parameters to the initial "closed economy". We consider a period to be two years. We assume a working span of $J_R = 25$ periods, and producing offspring at $J_k = 15$. That is, a worker is born at age 18, works for 50 years, and becomes parent (of an 18 year old) at age 48. We calibrate R^* to an annual risk-free rate of 1.6 percent, and calibrate β to match a mean wealth over annual income ratio of approximately 4–a standard number in the literature. We calibrate

the altruistic parameter $\hat{\lambda}$ such that annual transfers (intended, bequests, and college payments) amount to about to 30% of total mean wealth, as documented in Gale and Scholz (1994).

We assume that the household consumption bundle is given by a CES aggregator over final sectoral goods of the form

$$\mathcal{C}(c_s, c_m) = \left(\sum_{i=s,m} \nu_i^{1/\rho} c_i^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}$$

and set $\nu_s = 1 - \nu_m = 0.74$ and $\rho = 0.5$. These values are standard in the literature and deliver predictions of the model consistent with observed expenditure shares. The idiosyncratic productivity shock x is assumed to follow an AR(1) process in logs with persistence of $\rho_x = 0.9$ and standard deciation of $\sigma_x = 0.25$ at annual frequency (Floden and Lindé, 2001). We convert the process to a two-year duration and discretize it following Tauchen (1986).

We assume that the sector-specific taste shocks follow a Gumbel distribution with variance ρ_ϵ, identical to all workers. Similarly, we also assume all workers face the same cost of switching industry within region, $\psi_{je}(i, i') = \bar{\psi}$ for all $i \neq i'$–and zero otherwise. We follow Artuç et al. (2010) and calibrate the switching costs $\bar{\psi}$ to match an annual sectoral persistence of approximately 97 percent.

The borrowing constraint is set to zero, except for workers who go to college. College students can borrow up to $a_{1,c}$, which we calibrate such that 50% of the average cost of education $q_{sr}\kappa_r$ can be borrowed. This initial loan has to be repaid in the next 14 years: $a_{jc} = a_{1c}\ \forall j \leq 7$, and $a_{jc} = 0$ $\forall j > 7$. Finally, we calibrate the cost of education κ_r such that college expenses are approximately ten percent of total income. Turning to the education taste shocks, we follow Daruich (2023) and assume that these shocks are distributed according to a log-normal distribution with mean m_{e_p}, where $e_p \in \{c, n\}$, and variance σ_e^2, that is, $\ln \phi \sim \mathcal{N}(m_{e_p}, \sigma^2)$, for $e_p = \{c, n\}$. We calibrate the parameters of this distribution such that the share of college educated in the steady state is 36 percent, in line with American Community Survey (ACS) data for 1990, and the persistence in inter-generational education is 77 percent.

We use standard values for technology parameters. For the final good technology, we assume identical technologies across sectors: $\omega_i = 0.7$ and $\eta_i = 4$. Hence, we consider a trade elasticity in line with the literature. For intermediate goods technology, we assume $\sigma = 2$. We calibrate the intensity in college workers, γ_i, to match the share of college labor earnings relative to total labor earnings in each sector in the U.S. in 1990. As expected, Table 5 shows that $\gamma_{\mathbf{s}} > \gamma_{\mathbf{m}}$, implying that, on average, services are more intensive in college workers. The college share in services is 49 percent, while it is 31 percent in manufacturing.

We choose trade iceberg costs τ_i^* in the "closed economy" to match home-biases in each sector in 1990, equal to 0.90 in manufacturing and 0.98 in services. For the "open economy", we recalibrate τ_i^* to match a home-bias of 0.75 in manufacturing and equal to 0.98 in services, which correspond to the U.S. values for 2010. Finally, we calibrate the demand shifter $\bar{B}_i^*$ to match exports as a share of total expenditures in each sector in 1990.

Table 5 summarizes our calibration and provides data on the moments we target to discipline

some of the parameters. Table 6 presents some results for non-targeted moments in the steady state. The model delivers a reasonable wage premium, and a realistic wealth distribution.

Table 5: Calibration: External Parameters and Internal with Targeted Moments

	Parameters		Target	Data	Model
Preferences	ν_s	0.74	*External*	—	—
	ρ	0.5	*External*	—	—
Education	$\underline{a}_{1c}$	-0.10	Share of cost that can be borrowed $(-q\underline{a}_{1c}/q_s\kappa)$	0.50	0.48
	κ	0.19	Cost of college as mean of income	0.20	0.39
Savings	β	0.98	Wealth to income ratio	4	3.05
	$\hat{\lambda}$	0.45	Transfers to wealth ratio		0.30
Technologies	σ	2	*External*	—	—
	γ_s	0.55	Wages of non-college workers in services	0.41	0.38
	γ_m	0.40	Wages of college workers in manufacturing	0.07	0.06
			Wages of non-college workers in manufacturing	0.16	0.17
			Wages of non-college workers in services	0.37	0.39
Trade	τ_s	4.39	Home bias in services	0.98	0.98
	τ_m	2.17	Home bias in manufacturing	0.90	0.90
	B_s	0.01	Export share in services	0.02	0.02
	B_m	0.02	Export share in manufacturing	0.09	0.09

Table 6: Calibration: Non-targeted Moments

Moment		Model	Data
Wage premium (raw)		1.39	
Wage premium (adjusted)		1.52	
Trade balance (share of GDP)		-0.03	$\approx$ -0.012
Wealth distribution	1st quintile	0.00	
	2nd quintile	0.04	
	2nd quintile	0.10	
	2nd quintile	0.21	
	2nd quintile	0.65	

4 Quantitative Exercises

Trade openness in the model is then determined by the iceberg cost of importing goods τ^*_{it}. We consider a period of trade liberalization as one-time permanent decrease in the cost of imported goods τ^*_{it}. In particular, we start the economy at a "closed economy" steady-state with a high τ^*_i, and analyze the effect of a decline in τ^*_i to it's "open economy" steady-state value. We assume the decline in τ^*_{it} is unexpected, but there is perfect foresight from there onwards.

We start by describing education policies in steady-state which are key to the workings of the model. We then describe how the effects of trade openness differ across regions. Finally, we discuss the model prediction for college enrollment and its welfare implications. The next section compares welfare results with a *fixed education model*.

4.1 Education decisions: households' wealth matters

Before moving to the effect of trade openness, it's insightful to understand how education decision are made in the model. Figure 2 describes this policy. The solid lines show the probability of attending college (left axis) as a function of the parent's transfer, Φ, for different levels of the newborn's productivity, x. The dashed line shows the distribution of transfers for different levels of parents' productivities, x_p (right axis).

Below a certain transfer threshold, newborns will low levels of productivity do not acquire a college education simply because it is impossible for them to pay for it. Above this threshold, the probability of attending college increases drastically, and only declines slightly as transfers increase. For very large transfers, the probability of a newborn attending college does not depend on her productivity, as college basically becomes a parents' gift without consequences for a newborn's future consumption. Importantly, more productive parents are usually wealthier, and make larger transfers to their newborns.

The striking feature of Figure 2 is that, given a level of transfers above a certain threshold, the probability of going to college is remarkably similar regardless of the parents' productivities. What really drives the difference in college enrollments is the transfers that parents make. Low productivity parents give little transfers to their kids whose productivity is also very likely low, while higher productivity parents transfer enough resources so their kids go to college. Thus, college enrollment in the model crucially depends on the parents' wealth and transfers.

As we show below, trade openness leads to persistent differences in labor income across different types of workers. These differences not only affect the relative return to college, but also transfers to newborns, contributing to differential enrollment rate across households wealth.

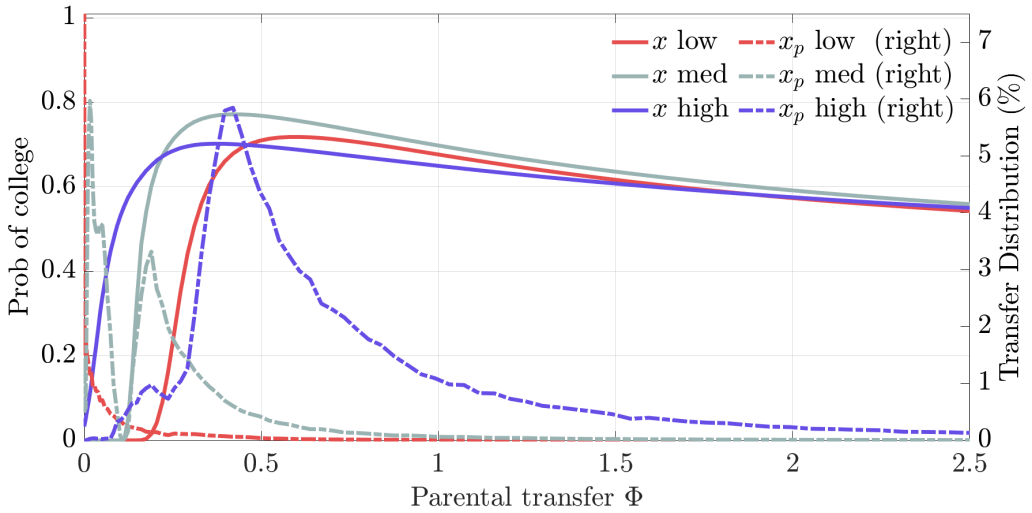
4.2 The Dynamic Effects of Trade Openness

We now turn to the dynamic effects of trade openness. We start discussing the cross-regional differences in labor market outcomes in response to the trade shock, and then discuss cross-regional differences in college enrollment. Finally, we discuss how households' wealth shapes college enrollment decisions.

4.2.1 Cross-regional differences

Labor-income responses.—Trade openness leads to heterogeneous responses in labor income, largely depending on workers labor market (region and sector), as Figure 3 shows. Workers in manufacturing undergo large declines in real wages due to the shock, while workers in services experience wage gains. The shock leads to a sizable switch in expenditure on manufacturing goods from those

Figure 2: Steady State Education Policies



Notes: Education policy in the closed steady-state as a function transfers Φ received by newborn. The left y-axis shows the probability of going to college, and the right y-axis show the probability of receiving that level of transfers. Each line corresponds to a different level of parents' productivity.

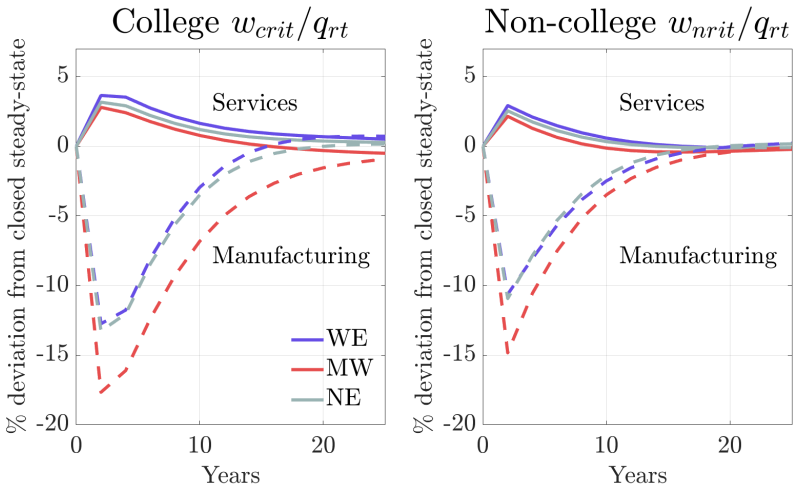
produced domestically, to those produced abroad. Therefore, as the domestic production of manufacturing declines, workers in this sector experience a sizable decline in real wages. The expansion in the services sector generates the increase in the real wages of workers in that sector.

The rationale of wage dynamics, as previously explained, is in line with the canonical Heckscher-Ohlin model. The cost of imports declines the most for manufacturing goods, which leads to expenditure switching towards foreign manufacturing goods, generating lower demand for domestically produced manufactures. In turn, wages decline more in the manufacturing sector. At the same time, wages in services increase to reallocate workers from manufacturing to services.

In line with our empirical analysis in Section 2, the wage responses across regions are amplified by the level of import competition exposure. In the more exposed region, the Midwest, real wages in manufacturing fall the most and in services increase the least. Note that these differentials in real wages across regions are greatest on impact, but become smaller as time evolves and current workers not only switch sectors and locations—in line with previous findings in (Artuç et al., 2010; Dix-Carneiro, 2014; Caliendo et al., 2019)—but newborns also go to college and acquire skill. How do these labor-income dynamics relate to the return to college and college enrollment? We now turn to this question.

College wage premium and college enrollment.—Trade openness induces an increase in the college wage premium, as Figure 4 shows. The increase in imports of manufactures requires workers to reallocate from manufacturing to services. Given that manufacturing is more intensive than services in non-college workers, the reallocation is more pronounced for non-college workers, leading to a relative decline in the income of non-college workers. This is, the model implies a trade-induced increase in the college wage-premium for all regions, with a larger increase on impact in the initially

Figure 3: Evolution of Wages



Notes: Wage responses after the trade shock. Wages are deflated by the price of the final in each region q_{rt}. Responses are reported as percentage deviations from the "closed economy" steady-state.

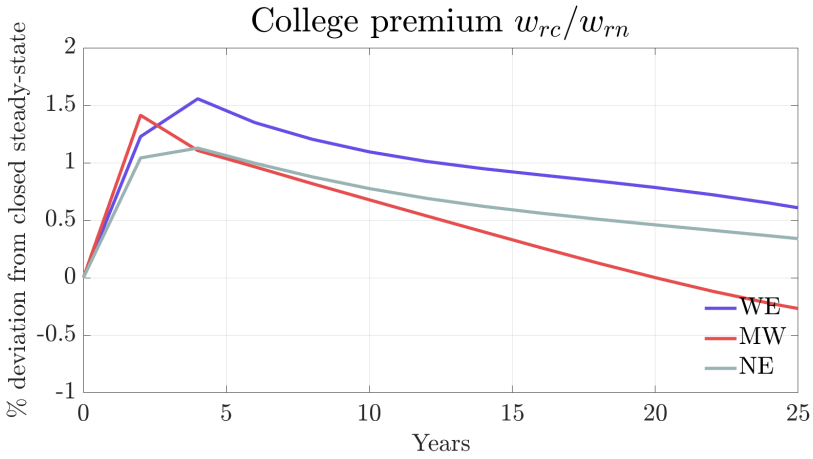
more exposed regions. While the nationwide college wage-premium (not shown) increases on impact by 1.2 percent, remains at its level for an additional period, then declines monotonically, the dynamics of this measure across locations are more complex because of the workers ability to reallocate across regions and sectors.

The increase in the college wage premium leads to a aggregate increase in college enrollment (not shown) of 0.6 percent after ten years. However, as shown in Figure 5, the increase in college enrollment differs markedly across regions. While the Northeast experiences an increase in college enrollment of approximately 0.4 percentage points after then years, this effect is more than doubled in the Midwest (1.4 percent)—the highly exposed region. Importantly, in line with the large increase in the college wage premium on impact, college enrollment increases the most on impact. Over time, collge enrollment converges to a new and higher level in the new steady state. Note that this is in line with a new steady state in which the return to college is higher permanentely because of the permanente nature of the shock.

In line with the evolution of real wages, Figure 6 shows that workers leave the Midwest. These workers migrate to other regions, primarily to the West, the region in which output of services expands the most.

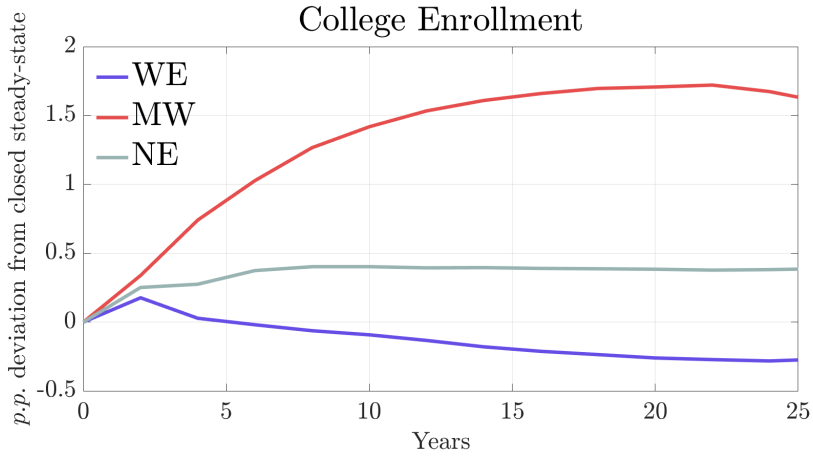
Cross-sectional regression: model vs data.—The model predicts higher college enrollment in the more exposed regions, qualitatively in line with our empirical findings in Section 2.3. We further show that model is quantitatively consistent with the data as well. Figure 7 considers the change in college enrollment in the three regions after the trade shock, and plots these changes against the change in import penetration of each region in the model. The model generated data is represented by the three dots. The black solid line represents the estimated relation between import penetration and college enrollment, adjusting the intercept so that it goes through the mid-exposed region—the

Figure 4: Evolution of Wage Premium



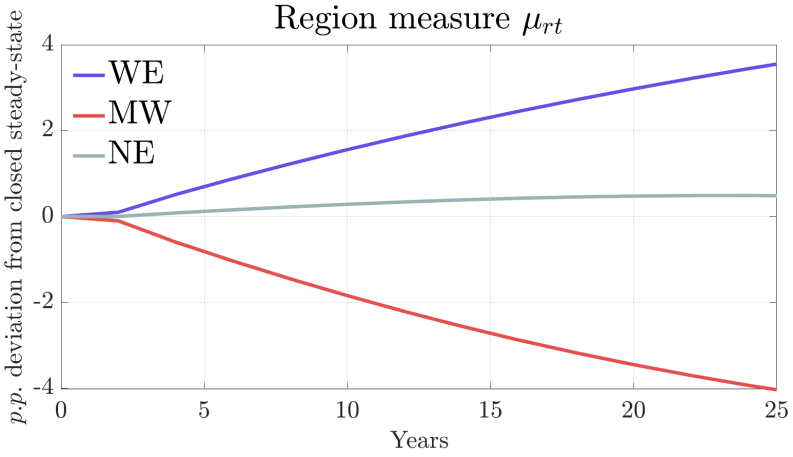
Notes: Wage premium after the trade shock. Wage premium is computed as the average labor-income of college workers relative to the one of non-college workers. Labor income includes the idiosyncratic productivity shock. Responses are reported as percentage deviations from the "closed economy" steady-state.

Figure 5: Evolution of College Enrollment



Notes: Measure of college workers after the trade shock. The measure includes college workers of all ages. Responses are reported as a percentage point difference from the "closed economy" steady-state.

Figure 6: Evolution of Employment



Notes: Measure of all workers after the trade shock. Responses are reported as a percentage point difference from the "closed economy" steady-state.

Northeast—as the estimates are only informative about the differences across regions, but not its level. The model is able to replicate our empirical results remarkably well, especially since they are not part of our calibration targets. We think of this as an interesting validation of the model.

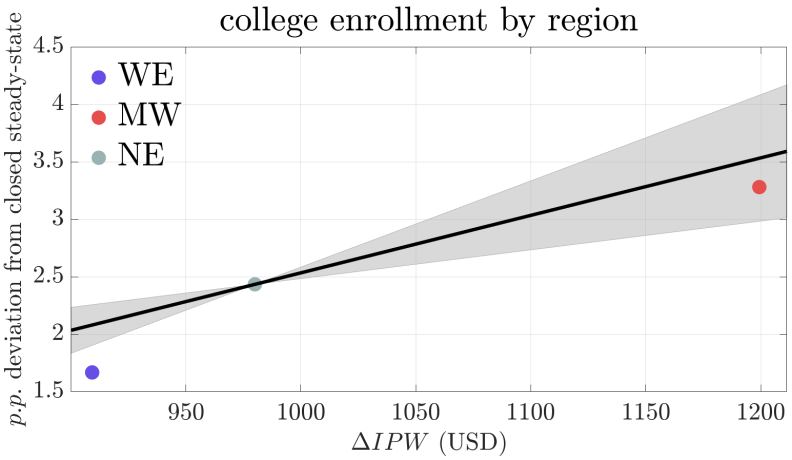
How about the effects on college enrollment across the wealth distribution? Figure 8 compares the results from our model to those obtained in the data in Section 2.3. The black line shows the estimates we obtianed previously, while the blue line shows the estimates that we obtain from the model. The model does a remarkable job in generating the hump-shape in estimates across households' wealth distribution. The enrollment responses across households in the Figure is actually remarkably similar to one estimated in Figure 1. Including the non-monotonicity for the top wealth quartile, who are newborns already likely to go college absent the shock. Again, we see these quantitative results as an interest validation of the model.

Lastly, Figure 9 considers changes in labor income, and compares the estimates that we obtain in our model with those estimated in Section 2.

4.2.2 Who goes to college more?

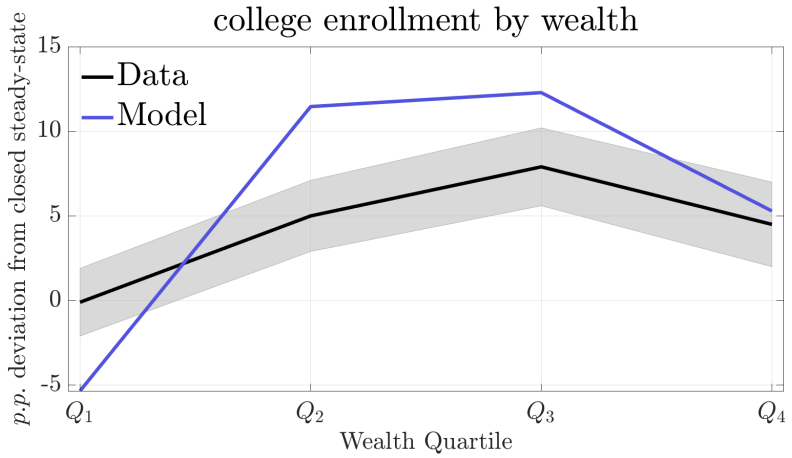
Trade openness induces an increase in college enrollment, especially in the more exposed region. While Figure 8 shows that the model can mach the aggregate pattern for college enrollment, we can also exploit the model to explore how enrollment changes in each region across the wealth distirbution. As shown in Figure 10, college enrollment across the wealth distribution can look quite different across locations. The figure shows college enrollment across the wealth distribution, for the West (left panel) and the Midwest (right panel). For the top wealth quartiles, enrollment remains relatively unchanged in the Midwest, but it actually declines in the West. Note that in the Midwest, the bottom quartile experiences an increase in college enrollment, but well that observed in the West.

Figure 7: Cross-regional Regression: Model vs Data for College Enrollment



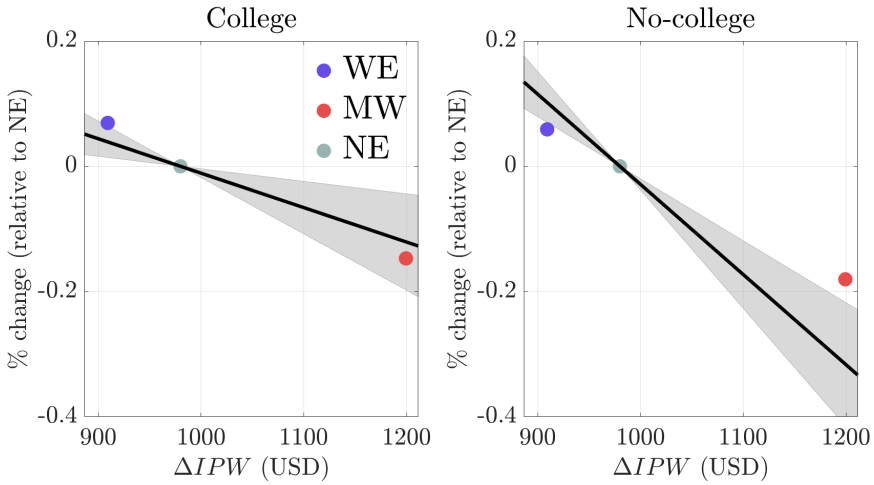
Notes: Import penetration for each region in the model is computed as in equation (1). Changes are computed using the "closed economy" steady-state as initial point, and ten years after the trade shock as the second point. Model units are transformed into 1990 U.S. dollars using average labor income. See Appendix C for more details.

Figure 8: Cross-regional Regression: Model vs Data for College Enrollment



Notes: Import penetration for each region in the model is computed as in equation (1). Changes are computed using the "closed economy" steady-state as initial point, and ten years after the trade shock as the second point. Model units are transformed into 1990 U.S. dollars using average labor income. See Appendix C for more details.

Figure 9: Cross-regional Regression: Model vs Data for Labor Earnings (30-55)



Notes: Import penetration for each region in the model is computed as in equation (1). Changes are computed using the "closed economy" steady-state as initial point, and ten years after the trade shock as the second point. Model units are transformed into 1990 U.S. dollars using average labor income. See Appendix C for more details.

The heterogeneity in enrollment responses comes not only from households' wealth but also from parent's sector. Figure 11 shows college enrollment in the Midwest when parents work in services (left panel) and manufacturing (right panel). The responses are computed at the period of the trade shock–on impact–and after a generation–after J_R periods.

On impact, newborns in poorer households enroll into college less for the case of newborns with parents in srvices—see Appendix B for an empirical validation of this result.[19] However, after a generation, workers in new cohorts enroll more into college, including the ones in the poorer households.

The differences in enrollment—across households and over time—are driven by the responses of *intervivos* transfers. Figure 12 plots transfers in the high exposed region, across the wealth distribution, from parents in services (left panel) and in manufacturing (right panel). Parents in service increase transfers to newborns, both on impact and after a generation. Parents in manufacturing increase transfers after a generation, but they cannot afford to do so immediately after the trade shocks since income decreases substantially for these households.

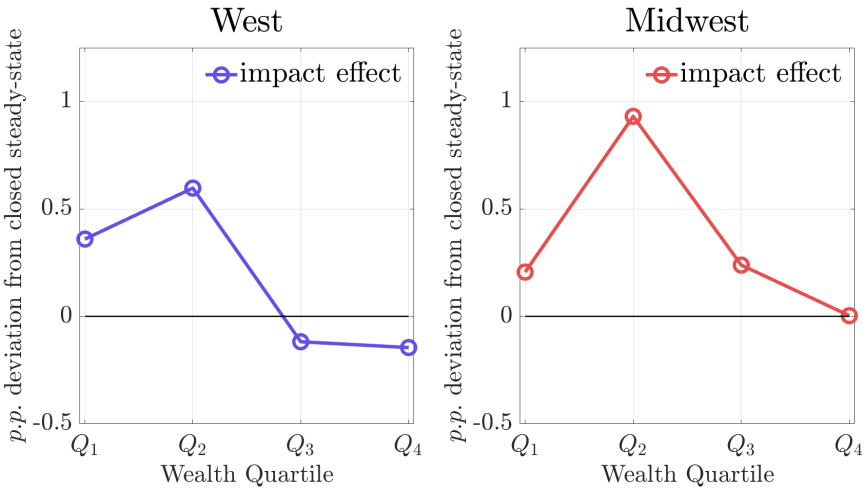
Thus, skill acquisition serves as a margin of adjustment available to new generations of workers. This margin is available to all workers in the long-run, and for new generations of workers at the time of the shock, but only for those who can afford it.

4.2.3 The welfare consequences of trade openness

The welfare gains of trade openness are heterogeneous across regions, wealth, sector, and time. Figure 13 plots welfare gains on impact—measured as consumption equivalents—for the low exposure

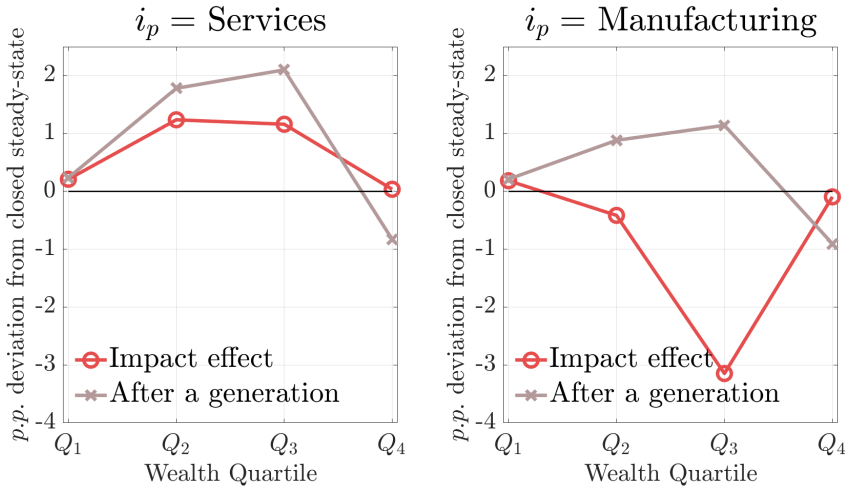
[19] We estimate similar effects of parent's sector on individuals college enrollment using CPS data. See Appendix B.

Figure 10: Change in College Enrollment



Notes: Measure of college enrollment for newborns, in each region and wealth quartile. Wealth distribution is computed using all regions. Responses are reported as a percentage point difference from the "closed economy" steady-state. See Appendix C for more details.

Figure 11: Change in College Enrollment by sector - High exposure region



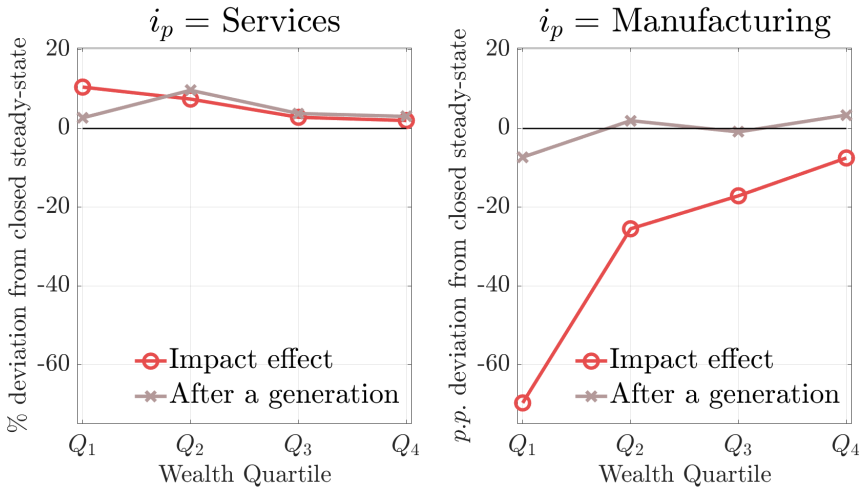
Notes: Measure of college enrollment for newborns in the high exposure region, for each of parents' sector and wealth quartile. Wealth distribution is computed using all regions, Appendix C for more details. Responses are reported as a percentage point difference from the "closed economy" steady-state.

region (left panel) and the high exposure region (right panel).[20] For both regions, we plot welfare gains for all education levels and sectors.

As before, welfare gains/losses are small for workers in the low exposure region. The welfare effects are much larger in the high exposure region. As with wages, workers in the services sector gain the most, while workers in manufacturing see the largest losses. Wealth also matters, with largest gains/losses accumulated on poorer workers, who rely more on their labor income.

[20]The consumption equivalent measures the permanent change in consumption a worker should receive in order to be indifferent between the initial "closed economy" steady-state and the transition. Thus a positive consumption equivalent means a welfare gain from trade openness. See Appendix C for details.

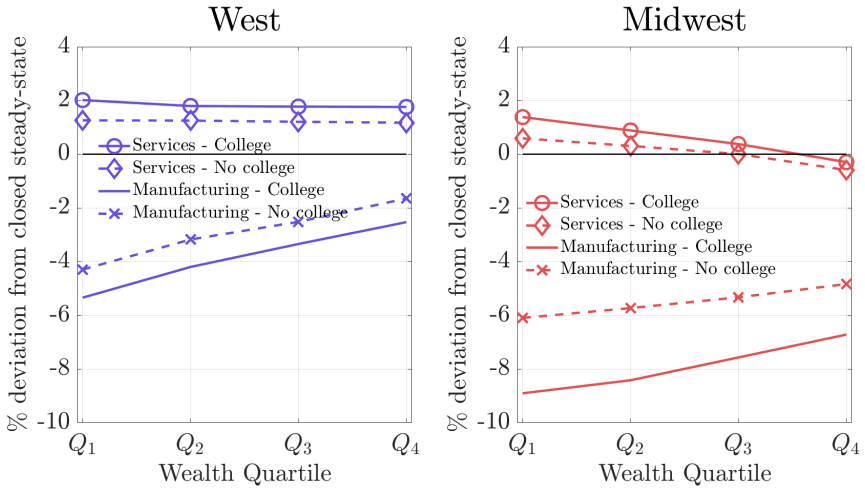
Figure 12: *Intervivos* transfers by sector - High exposure region



Notes: Measure of transfer to newborns in the high exposure region, for each of parents' sector and wealth quartile. Wealth distribution is computed using all regions. Responses are reported as a percentage deviation from the "closed economy" steady-state. See Appendix C for more details.

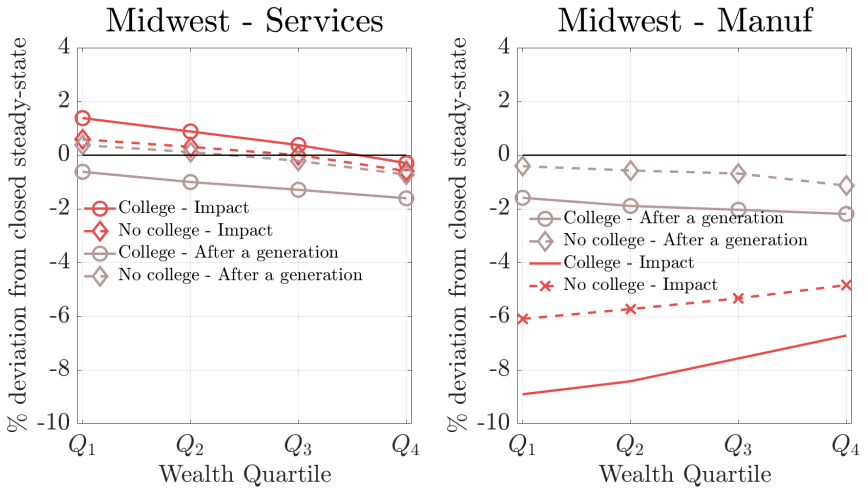
Figure 14 shows welfare gains for the high exposure region over time, for each education level in services (left panel) and manufactures (right panel). The initial welfare losses of workers in manufacturing is fully reverted after a generation. Thus, while there are initial losses, there are only gains of freer trade in the long-run. Importantly, the initial differential gains even out over time, and they are almost identical regardless of the workers' sector and/or education level. As we argue in next section, endogenous skill acquisition is a key margin of adjustment to even out welfare gains in the long-run.

Figure 13: Consumption equivalents by region and sector



Notes: Consumption equivalent in the period of trade openness. Wealth distribution is computed using all regions. Consumption equivalents are reported as a percentage deviation from the "closed economy" steady-state consumption. See Appendix C for more details.

Figure 14: Consumption equivalents for the high region over time



Notes: Consumption equivalent in the high exposure region at the period of trade openness and after a generation. Wealth distribution is computed using all regions. Consumption equivalents are reported as a percentage deviation from the "closed economy" steady-state consumption. See Appendix C for more details.

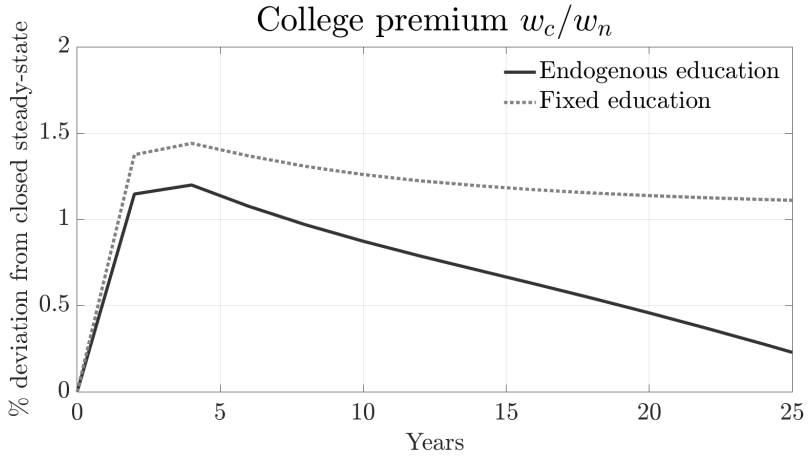
5 Welfare implications of skill acquisition

In order to gauge the welfare implications of endogenous skill acquisition, we use an alternative model where education is given and not a workers' choice. We refer to this alternative as *fixed education* model, and label as *endogenous education* model to the benchmark of previous sections. In particular, we assume that the education level in the *fixed education* model is inherited from parents. This implies the measure of college workers remains fixed through time. To ease comparison with *endogenous education* model, we assume the same measure of college workers in the *fixed education* as in the "closed economy" steady-state of the *endogenous education* model. Furthermore, workers who inherit a college education still have to pay the cost of college. The sectoral choice remains as in the *endogenous education* model. Thus, we remove skill acquisition as a margin of adjustment to trade openness, but keep sectoral switching as an available margin. Appendix E contains more details on the *fixed education* model.

The wage premium increases initially the same *fixed education* and the *endogenous education* models, as Figure 15 shows. This is expected, since both models have the same amount of college workers at the moment of the trade shock. However, because the measure college workers increase, the wage premium in the *endogenous education* model settles o a much lower level that in the *fixed education* model. This is, endogenous skill acquisition ameliorates the initial uneven wage gains of trade.

A similar rationale carries to welfare gains. Figure 16 shows the welfare gains college and non-college workers in both models, on impact and after a generation. On impact, both models predict similar welfare gains: a 3.25% consumption equivalent gain for college workers, and a 1.5% gain for non-college workers. In the long-run, however, consumption equivalent differences

Figure 15: Wage Premium in *endogenous education* and *fixed education* models - high exposure region



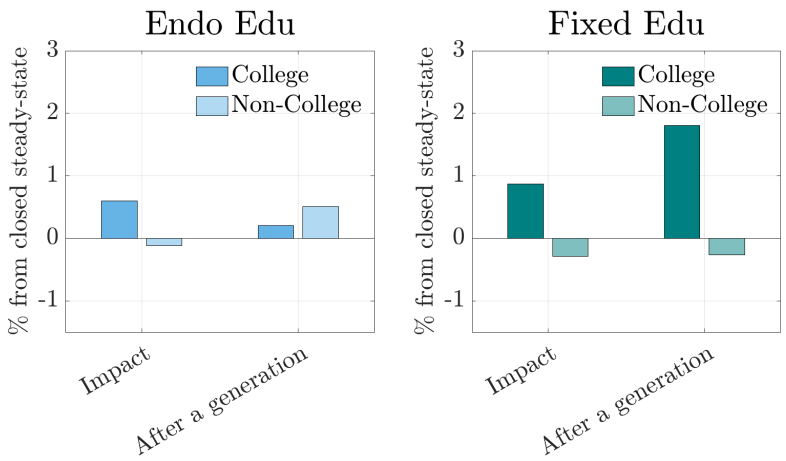
Notes: Wage premium after the trade shock. Wage premium is computed as the average labor-income of college workers relative to the one of non-college workers. Labor income includes the idiosyncratic productivity shock. Responses are reported as percentage deviations from the "closed economy" steady-state.

almost disappear in the *endogenous education* model: with gains of 2.5% and 2.1% for college and non-college workers, respectively. Yet, the welfare gains differences remain about the same over time in the *fixed education* model. We conclude that endogenous skill-acquisition is a key margin of adjustment when evaluating the effects of trade openness.

6 Conclusion

We argued that trade openness can have unequal effects on heterogeneous households, especially in the short run. An increase in the skill premium induces households to invest in education, but this decision may be constrained by the household's wealth. In turn, poor-unskilled workers take the longest to acquire skills and are therefore the last to experience positive gains from trade openness. When we calibrate the model to the United States, we find that several households find trade openness detrimental. We explore various policies to address this concern.

Figure 16: Consumption equivalents over time in *endogenous education* and *fixed education* models - high exposure region



Notes: Consumption equivalent in the high exposure region at the period of trade openness and after a generation. Wealth distribution is computed using all regions. Consumption equivalents are reported as a percentage deviation from the "closed economy" steady-state consumption. See Appendix E for more details.

References

Abbott, Brant, Giovanni Gallipoli, Costas Meghir, and Giovanni L. Violante, "Education Policy and Intergenerational Transfers in Equilibrium," *Journal of Political Economy*, 2019, *127* (6), 2569–2624.

Adão, Rodrigo, Martin Beraja, and Nitya Pandalai-Nayar, "Technological Transitions with Skill Heterogeneity Across Generations," Working Paper 26625, National Bureau of Economic Research January 2020.

Aiyagari, Rao S, "Uninsured Idiosyncratic Risk and Aggregate Saving," *The Quarterly Journal of Economics*, 1994, *109*, 659–684.

Antràs, Pol, Alonso de Gortari, and Oleg Itskhoki, "Globalization, inequality and welfare," *Journal of International Economics*, 2017, *108*, 387 – 412.

Artuç, Erhan, Shubham Chaudhuri, and John McLaren, "Trade Shocks and Labor Adjustment: A Structural Empirical Approach," *American Economic Review*, June 2010, *100* (3), 1008–45.

Atkin, David, "Endogenous Skill Acquisition and Export Manufacturing in Mexico," *American Economic Review*, August 2016, *106* (8), 2046–85.

Autor, David H., David Dorn, and Gordon H. Hanson, "The China Syndrome: Local Labor Market Effects of Import Competition in the United States," *American Economic Review*, October 2013, *103* (6), 2121–68.

_ , _ , and _ , "The China Shock: Learning from Labor-Market Adjustment to Large Changes in Trade," *Annual Review of Economics*, 2016, *8* (1), 205–240.

Blanchard, Emily J. and William W. Olney, "Globalization and human capital investment: Export composition drives educational attainment," *Journal of International Economics*, 2017, *106*, 165 – 183.

Burstein, Ariel and Jonathan Vogel, "International Trade, Technology, and the Skill Premium," *Journal of Political Economy*, 2017, *125* (5), 1356–1412.

_ , Eduardo Morales, and Jonathan Vogel, "Changes in between-group inequality: computers, occupations, and international trade," Manuscript, UCLA 2016.

_ , Javier Cravino, and Jonathan Vogel, "Importing Skill-Biased Technology," *American Economic Journal: Macroeconomics*, April 2013, *5* (2), 32–71.

Caliendo, Lorenzo, Maximiliano Dvorkin, and Fernando Parro, "Trade and Labor Market Dynamics: General Equilibrium Analysis of the China Trade Shock," *Econometrica*, 2019, *87* (3), 741–835.

Carroll, Daniel and Sewon Hur, "On the distributional effects of international tariffs," *International Economic Review*, 2023, *64* (4), 1311–1346.

Carroll, Daniel R and Sewon Hur, "On the heterogeneous welfare gains and losses from trade," *Journal of Monetary Economics*, 2020, *109*, 1–16.

Charles, Kerwin Kofi, Erik Hurst, and Matthew J Notowidigdo, "Housing Booms and Busts, Labor Market Opportunities, and College Attendance," Working Paper 21587, National Bureau of Economic Research September 2015.

Coçar, A. Kerem, Nezih Guner, and James Tybout, "Firm Dynamics, Job Turnover, and Wage Distributions in an Open Economy," *American Economic Review*, March 2016, *106* (3), 625–63.

Cravino, Javier and Sebastian Sotelo, "Trade Induced Structural Change and the Skill Premium," Working Paper 23503, National Bureau of Economic Research June 2017.

Danziger, Eliav, "Skill acquisition and the dynamics of trade-induced inequality," *Journal of International Economics*, 2017, *107*, 60 – 74.

Daruich, Diego, "The macroeconomic consequences of early childhood development policies," *FRB St. Louis Working Paper*, 2023, (2018-29).

Dix-Carneiro, Rafael, "Trade Liberalization and Labor Market Dynamics," *Econometrica*, 2014, *82* (3), 825–885.

_ , João Paulo Pessoa, Ricardo Reyes-Heroles, and Sharon Traiberman, "Globalization, Trade Imbalances, and Labor Market Adjustment*," *The Quarterly Journal of Economics*, 01 2023, *138* (2), 1109–1171.

Dvorkin, Maximiliano A, "Heterogeneous Agents Dynamic Spatial General Equilibrium," Technical Report 2023.

Eagan, M. K., E. B. Stolzenberg, J. J. Ramirez, M. C. Aragon, M. R. Suchard, and C. Rios-Aguilar, *The American freshman: Fifty-Year trends, 1966-2015*, Los Angeles: Higher Education Research Institute, UCLA, 2016.

Findlay, Ronald and Henryk Kierzkowski, "International Trade and Human Capital: A Simple General Equilibrium Model," *Journal of Political Economy*, 1983, *91* (6), 957–978.

Floden, Martin and Jesper Lindé, "Idiosyncratic risk in the United States and Sweden: Is there a role for government insurance?," *Review of Economic dynamics*, 2001, *4* (2), 406–437.

Gale, William G. and John Karl Scholz, "Intergenerational Transfers and the Accumulation of Wealth," *Journal of Economic Perspectives*, December 1994, *8* (4), 145–160.

Giannone, Elisa, Qi Li, Nuno Paixao, and Xinle Pang, "Unpacking Moving," Technical Report, Working Paper 2023.

Greaney, Brian, "The distributional effects of uneven regional growth," *University of Washington, mimeograph.[6]*, 2020.

Greenland, Andrew and John Lopresti, "Import exposure and human capital adjustment: Evidence from the U.S.," *Journal of International Economics*, 2016, *100*, 50 – 60.

_ , _ , and Peter McHenry, "Import Competition and Internal Migration," *The Review of Economics and Statistics*, 2019, *101* (1), 44–59.

Helpman, Elhanan, Oleg Itskhoki, and Stephen Redding, "Inequality and Unemployment in a Global Economy," *Econometrica*, 2010, *78* (4), 1239–1283.

_ , _ , Marc-Andreas Muendler, and Stephen J. Redding, "Trade and Inequality: From Theory to Estimation," *The Review of Economic Studies*, 2017, *84* (1), 357–405.

Kim, Ryan and Jonathan Vogel, "Trade and Welfare (Across Local Labor Markets)," Working Paper 27133, National Bureau of Economic Research May 2020.

Lochner, Lance and Alexander Monge-Naranjo, "Credit Constraints in Education," *Annual Review of Economics*, 2012, *4* (1), 225–256.

Lovenheim, Michael F, "The effect of liquid housing wealth on college enrollment," *Journal of Labor Economics*, 2011, *29* (4), 741–771.

Lyon, Spencer and Michael Waugh, "Redistributing the Gains From Trade Through Progressive Taxation," Manuscript, NYU 2018.

_ and _ , "Quantifying the Losses from Trade," Manuscript, NYU 2019.

Ma, Xiao, Alejandro Nakab, and Yiran Zhang, "Skill Acquisition and the Gains from Trade: A Cross-country Quantitative Analysis," 2023.

Pierce, Justin R. and Peter K. Schott, "The Surprisingly Swift Decline of US Manufacturing Employment," *American Economic Review*, July 2016, *106* (7), 1632–62.

Solis, Alex, "Credit Access and College Enrollment," *Journal of Political Economy*, 2017, *125* (2), 562–622.

Tauchen, George, "Finite State Markov-Chain Approximations to Univariate and Vector Autoregressions," *Economic Letters*, 1986, *2* (20), 177–181.

Traiberman, Sharo, "Occupations and Import Competition," Manuscript, NYU 2018.

Waugh, Michael E, "Heterogeneous Agent Trade," Technical Report, National Bureau of Economic Research 2023.

A Appendix

A Trade Shocks and Skill Acquisition

The rich structure of the model we built in the previous section will allow us to carry out a quantitative analysis of how trade shocks affect workers over time. However, it is worth developing some intuition about the main mechanisms at play in the model before proceeding to the quantitative analysis. In order to do so, we will focus on a simplified version of the static block of the model with a single region, perfect labor mobility across sectors, no foreign demand for goods produced at home and same elasticities of substitution between skills across sectors. More specifically, we assume for the moment that $|\mathcal{R}| = \infty$, that agents' savings decisions and skill-acquisition choices have already been made optimally and that $\sigma \equiv \sigma_m = \sigma_s$. This will allow us to rely on two of the main theorems in International Trade to develop intuition, while only referencing to the simple dynamic mechanism telling us that an increase in the return to skill will increase the number of workers that decide to acquire an education. To simplify our exposition, we also assume that the consumption aggregator is given by a Cobb-Douglas function with exponents given by ν_j for $j \in \{s, m\}$.

How do changes in import prices affect the skill premium? Consider a decline in the trade costs that domestic final good producers in sector m pay for intermediate goods produced abroad. Assume that model parameters are such the decline in the price paid by producers leads to expenditure switching across countries and a decline in the relative price of sector m intermediate goods produced in the home country, p_m. The following is a version of the Stolper-Samuelson theorem for this experiment in our model.

Proposition A.1 (Stolper-Samuelson) *Given a distribution of skills across workers, a decrease in the relative price of the intermediate good produced domestically in sector m will decrease the wage of non-educated workers and increase that of educated workers if non-educated workers are used more intensively in the production of the intermediate good in sector m, that is, whenever the following condition holds given the wage premium, $\frac{w_c}{w_n}$, before the price change:*

$$\left(\frac{1-\gamma_m}{1-\gamma_s}\right)^{\sigma-1} > \frac{\gamma_m \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_m)}{\gamma_s \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_s)}. \tag{23}$$

Proof See Appendix A.1.

Consider the case of the United States, for which there is evidence that the manufacturing sector is intensive in non-educated workers.[21] Then, according to Proposition A.1 a decline the price that final goods producers pay for imported manufacturing goods would lead to an increase in the skill premium given a distribution of skills across workers.

[21] See Cravino and Sotelo (2017) for evidence on this feature for multiple countries.

How does an increase in the skill premium affect the distribution of skills across workers and production? Let us briefly turn to the dynamic block of the model. The model tells us that an increase in the skill premium will make the acquisition of education more attractive for new workers. This will in principle lead new generations of workers to become educated, gradually shifting the distribution of skills in the economy towards a more educated economy. This change in the distribution will in turn affect the comparative advantage of the home country, and therefore production, in line with Rybczynski's theorem.

Proposition A.2 (Rybczynski) *A shift in the distribution of skills in the economy towards more educated workers will increase the output of domestic intermediate goods produced in sector s and decrease the output of the other sector.*

Proof See Appendix A.2.

How do changes in output feed back into prices? From preferences we know that in equilibrium

$$\frac{q_m Q_m}{\nu_m} = \frac{q_s Q_s}{\nu_s}.$$

We also know that $p_i Y_i = p_i D_i = \omega_i \left(\frac{p_i}{q_i}\right)^{1-\eta_i} q_i Q_i$. Hence, if κ is not too big, then we obtain that in equilibrium the following condition must hold

$$\frac{Y_m}{Y_s} \approx \frac{\omega_s}{\omega_m} \frac{\nu_m}{\nu_s} \frac{p_s^{\eta_s}}{p_m^{\eta_m}} \frac{q_s^{1-\eta_s}}{q_m^{1-\eta_m}}.$$

For simplicity, let us assume that $\eta \equiv \eta_m = \eta_s$. Then, from the previous condition we obtain that

$$\hat{Y}_m - \hat{Y}_s \approx \eta \left(\hat{p}_s - \hat{p}_m\right) + (1-\eta)\left(\hat{q}_s - \hat{q}_m\right)$$

and if $p_s = 1$ and world prices are given we obtain that

$$\begin{aligned} \eta \hat{p}_m + (1-\eta)\,\hat{q}_m &\approx -\left(\hat{Y}_m - \hat{Y}_s\right) \Leftrightarrow \\ \hat{p}_m \left(\eta + (1-\eta)\,\phi\right) &\approx -\left(\hat{Y}_m - \hat{Y}_s\right) \end{aligned}$$

where ϕ is positive. Therefore, if $\hat{Y}_m - \hat{Y}_s > 0$, then $\hat{p}_m < 0$ which will counteract the initial Stolper-Samuelson forces.

A.1 Proof of Proposition A.1

For the Armington model consider a shock to p_m^* that leads to expenditure switching and a decline in the price produced at home.

Consider the unit-cost functions:

$$c_i\left(w_c, w_n, r\right) = \min_{L_{i,c}, L_{i,n}, K_i} \left\{ w_c L_{i,c} + w_n L_{i,n} + rK \middle| F_i\left(L_{i,c}, L_{i,n}, K_i\right) \geq 1 \right\},$$

where

$$F_i\left(L_{i,c},L_{i,n},K_i\right)=\left(\gamma_i^{\frac{1}{\sigma_i}}L_{i,c}^{\frac{\sigma_i-1}{\sigma_i}}+\left(1-\gamma_i\right)^{\frac{1}{\sigma_i}}L_{i,n}^{\frac{\sigma_i-1}{\sigma_i}}\right)^{\left(\frac{\sigma_i}{\sigma_i-1}\right)(1-\alpha_i)}K_i^{\alpha_i}.$$

Then we know that in this particular case

$$c_i\left(w_c,w_n,r\right)\propto\left(\gamma_i w_c^{1-\sigma_i}+\left(1-\gamma_i\right)w_n^{1-\sigma_i}\right)^{(1-\alpha_i)}\left(r\right)^{\alpha_i}$$

and that in general by the "envelope theorem"

$$\begin{aligned}\frac{\partial c_i\left(w_c,w_n,r\right)}{\partial w_e}&=a_{i,L_e}\left(w_c,w_n,r\right)\\\frac{\partial c_i\left(w_c,w_n,r\right)}{\partial r}&=a_{i,K}\left(w_c,w_n,r\right)\end{aligned}$$

for $e\in\{c,n\}$ where $a_{i,x}$ denotes the optimal choice for factor x as a function of factor prices to produce one unit of the good.

The zero-profit conditions imply that in equilibrium

$$\begin{aligned}p_m=c_m\left(w_c,w_n,r\right)&=\kappa_m\left(\gamma_m w_c^{1-\sigma_m}+\left(1-\gamma_m\right)w_n^{1-\sigma_m}\right)^{\left(\frac{1-\alpha_m}{1-\sigma_m}\right)}\left(r\right)^{\alpha_m},\\p_s=c_s\left(w_c,w_n,r\right)&=\kappa_s\left(\gamma_s w_c^{1-\sigma_s}+\left(1-\gamma_s\right)w_n^{1-\sigma_s}\right)^{\left(\frac{1-\alpha_m}{1-\sigma_m}\right)}\left(r\right)^{\alpha_s}.\end{aligned}$$

By totally differentiating these conditions we obtain

$$\begin{aligned}dp_i&=a_{i,L_c}dw_c+a_{i,L_n}dw_n+a_{i,K}dr\Rightarrow\\\frac{dp_i}{p_i}&=\frac{w_c a_{i,L_c}}{c_i}\frac{dw_c}{w_c}+\frac{w_n a_{i,L_n}}{c_i}\frac{dw_n}{w_n}+\frac{r a_{i,K}}{c_i}\frac{dr}{r}.\end{aligned}$$

Define cost shares by $\theta_{i,L_e}\equiv\frac{w_e a_{i,L_e}}{c_i}$ for $e\in\{c,n\}$ and $\theta_{i,K}\equiv\frac{r a_{i,K}}{c_i}$. Then we obtain that

$$\begin{aligned}\begin{pmatrix}\hat{p}_m\\\hat{p}_s\end{pmatrix}&=\begin{pmatrix}\theta_{m,L_c}&\theta_{m,L_n}&\theta_{m,K}\\\theta_{s,L_c}&\theta_{s,L_n}&\theta_{s,K}\end{pmatrix}\begin{pmatrix}\hat{w}_c\\\hat{w}_n\\\hat{r}\end{pmatrix}\\&=\begin{pmatrix}\theta_{m,L_c}&\theta_{m,L_n}\\\theta_{s,L_c}&\theta_{s,L_n}\end{pmatrix}\begin{pmatrix}\hat{w}_c\\\hat{w}_n\end{pmatrix}+\begin{pmatrix}\theta_{m,K}\\\theta_{s,K}\end{pmatrix}\hat{r}\end{aligned}$$

which implies that

$$\begin{pmatrix}\hat{w}_c\\\hat{w}_n\end{pmatrix}=\begin{pmatrix}\theta_{m,L_c}&\theta_{m,L_n}\\\theta_{s,L_c}&\theta_{s,L_n}\end{pmatrix}^{-1}\begin{pmatrix}\hat{p}_m-\theta_{m,K}\hat{r}\\\hat{p}_s-\theta_{s,K}\hat{r}\end{pmatrix}.$$

Asusmption 1 Assume that only the two types of labor are factors of production, that is, $\alpha_i=0$ for $i\in\{m,s\}$. Hence, $\theta_{m,K}=\theta_{s,K}=0$ and $\kappa_i=1$ for $i\in\{m,s\}$.

We now have that

$$\begin{pmatrix} \hat{w}_c \\ \hat{w}_n \end{pmatrix} = \begin{pmatrix} \theta_{m,L_c} & \theta_{m,L_n} \\ \theta_{s,L_c} & \theta_{s,L_n} \end{pmatrix}^{-1} \begin{pmatrix} \hat{p}_m \\ \hat{p}_s \end{pmatrix}$$
$$= \frac{1}{\det \theta} \begin{pmatrix} \theta_{s,L_n} & -\theta_{m,L_n} \\ -\theta_{s,L_c} & \theta_{m,L_c} \end{pmatrix} \begin{pmatrix} \hat{p}_m \\ \hat{p}_s \end{pmatrix}$$

where

$$\begin{aligned} \det \theta &= \theta_{m,L_c}\theta_{s,L_n} - \theta_{m,L_n}\theta_{s,L_c} \\ &= \theta_{m,L_c}\left(1-\theta_{s,L_c}\right) - \left(1-\theta_{m,L_c}\right)\theta_{s,L_c} \\ &= \theta_{m,L_c}\left(1-\theta_{s,L_c}\right) - \left(1-\theta_{m,L_c}\right)\theta_{s,L_c} \\ &= \theta_{m,L_c} - \theta_{s,L_c} = \theta_{s,L_n} - \theta_{m,L_n}. \end{aligned}$$

Therefore, we have that

$$\begin{aligned} \hat{w}_c &= \frac{\hat{p}_m\theta_{s,L_n} - \hat{p}_s\theta_{m,L_n}}{\theta_{s,L_n} - \theta_{m,L_n}} \\ &= \frac{\left(\theta_{m,L_n} - \theta_{s,L_n}\right)\hat{p}_s + \theta_{s,L_n}\left(\hat{p}_s - \hat{p}_m\right)}{\theta_{m,L_n} - \theta_{s,L_n}} \end{aligned}$$

and

$$\begin{aligned} \hat{w}_n &= \frac{\hat{p}_s\theta_{m,L_c} - \hat{p}_m\theta_{s,L_c}}{\theta_{m,L_c} - \theta_{s,L_c}} \\ &= \frac{\left(\theta_{s,L_c} - \theta_{m,L_c}\right)\hat{p}_m - \left(\hat{p}_s - \hat{p}_m\right)\theta_{m,L_c}}{\theta_{s,L_c} - \theta_{m,L_c}} \end{aligned}$$

Assumption 2 WLOG, assume that the manufacturing sector is intensive in low skilled workers, that is, $\theta_{m,L_n} - \theta_{s,L_n} > 0$, which implies that $\theta_{s,L_c} - \theta_{m,L_c} > 0$ given that $\theta_{i,L_c} + \theta_{i,L_n} = 1$ for $i \in \{m, s\}$.

Suppose that $\hat{p}_s - \hat{p}_m > 0$.

Given the previous assumptions, we obtain Stolper-Samuleson's result that

$$\hat{w}_c > \hat{p}_s > \hat{p}_m > \hat{w}_n.$$

Now, when does the assumption that $\theta_{m,L_n} - \theta_{s,L_n} > 0$ hold? In the case of Cobb-Douglas production functions this is clear. We have that $\theta_{i,L_n} \equiv \frac{w_n a_{i,L_n}}{c_i}$and

$$a_{i,L_n} = \frac{\partial}{\partial w_n}\left(\gamma_i w_c^{1-\sigma_i} + \left(1-\gamma_i\right)w_n^{1-\sigma_i}\right)^{\frac{1}{1-\sigma_i}} = \left(1-\gamma_i\right)\left(\frac{c_i}{w_n}\right)^{\sigma_i}.$$

Hence,

$$\theta_{m,L_n} - \theta_{s,L_n} = (1-\gamma_m)\left(\frac{c_m}{w_n}\right)^{\sigma_m - 1} - (1-\gamma_s)\left(\frac{c_s}{w_n}\right)^{\sigma_s - 1}.$$

Now, notice that

$$\frac{c_i}{w_n} = \left(\gamma_i \left(\frac{w_c}{w_n}\right)^{1-\sigma_i} + (1-\gamma_i)\right)^{\frac{1}{1-\sigma_i}}.$$

Assumption 3 Skills are gross substitutes in production and their elasticity of substitution is the same across sectors, that is, $\sigma_i > 1$ for $i \in \{m, s\}$ and $\sigma \equiv \sigma_m = \sigma_s$.

Then notice that

$$\begin{aligned}
\frac{c_m}{w_n} &> \frac{c_s}{w_n} \Leftrightarrow \\
\frac{1}{\left(\gamma_m \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_m)\right)^{\frac{1}{\sigma-1}}} &> \frac{1}{\left(\gamma_s \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_s)\right)^{\frac{1}{\sigma-1}}} \Leftrightarrow \\
\left(\gamma_s \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_s)\right)^{\frac{1}{\sigma-1}} &> \left(\gamma_m \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_m)\right)^{\frac{1}{\sigma-1}} \Leftrightarrow \\
\gamma_s \left(\frac{w_c}{w_n}\right)^{1-\sigma} - \gamma_m \left(\frac{w_c}{w_n}\right)^{1-\sigma} &> (1-\gamma_m) - (1-\gamma_s) \Leftrightarrow \\
1 &> \left(\frac{w_c}{w_n}\right)^{\sigma-1}.
\end{aligned}$$

Therefore, the only way to assure that $\theta_{m,L_n} - \theta_{s,L_n} > 0$ as long as $\gamma_s > \gamma_m$ is if $\frac{w_c}{w_n} < 1$, which is counter-factual. Hence, if $\frac{w_c}{w_n} > 1$ we need that

$$\frac{1-\gamma_m}{1-\gamma_s} > \frac{c_s}{c_m} = \left(\frac{\gamma_m \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_m)}{\gamma_s \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_s)}\right)^{\frac{1}{\sigma-1}}$$

which is equivalent to

$$\left(\frac{1-\gamma_m}{1-\gamma_s}\right)^{\sigma-1} > \frac{\gamma_m \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_m)}{\gamma_s \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_s)}.$$

A.2 Proof of Proposition A.2

Let Y_i denote total production of good i. Notice that because of constant marginal costs, then total factors used in the production of good i are $L_{i,c} = a_{i,L_c} Y_i$ and $L_{i,n} = a_{i,L_n} Y_i$. Hence, factor market

clearing is given by

$$a_{m,L_c}Y_m + a_{s,L_c}Y_s = L_c,$$
$$a_{m,L_n}Y_m + a_{s,L_n}Y_s = L_n.$$

By totally differentiating this system of equations we obtain

$$a_{m,L_c}dY_m + a_{s,L_c}dY_s = dL_c,$$
$$a_{m,L_n}dY_m + a_{s,L_n}dY_s = dL_n,$$

where we have used the fact that a_{i,L_c} and a_{i,L_n} do not change if prices do not change. Hence, we obtain that

$$\frac{a_{m,L_c}Y_m}{L_c}\frac{dY_m}{Y_m} + \frac{a_{s,L_c}Y_s}{L_c}\frac{dY_s}{Y_s} = \frac{dL_c}{L_c},$$
$$\frac{a_{m,L_n}Y_m}{L_n}\frac{dY_m}{Y_m} + \frac{a_{s,L_n}Y_s}{L_n}\frac{dY_s}{Y_s} = \frac{dL_n}{L_n},$$

which we can rewrite as

$$\lambda_{m,L_c}\hat{Y}_m + \lambda_{s,L_c}\hat{Y}_s = \hat{L}_c,$$
$$\lambda_{m,L_n}\hat{Y}_m + \lambda_{s,L_n}\hat{Y}_s = \hat{L}_n,$$

where λ_{i,L_e} measure the fraction of factor L_e employed in industry i.

Inverting this system of equations we obtain

$$\begin{pmatrix} \hat{Y}_m \\ \hat{Y}_s \end{pmatrix} = \begin{pmatrix} \lambda_{m,L_c} & \lambda_{s,L_c} \\ \lambda_{m,L_n} & \lambda_{s,L_n} \end{pmatrix}^{-1} \begin{pmatrix} \hat{L}_c \\ \hat{L}_n \end{pmatrix}$$
$$= \frac{1}{\det\lambda} \begin{pmatrix} \lambda_{s,L_n} & -\lambda_{s,L_c} \\ -\lambda_{m,L_n} & \lambda_{m,L_c} \end{pmatrix} \begin{pmatrix} \hat{L}_c \\ \hat{L}_n \end{pmatrix}$$

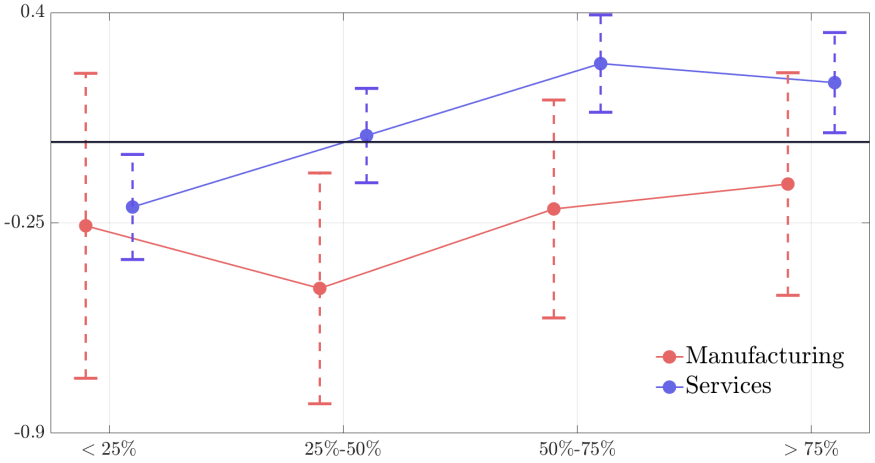
where

$$\begin{aligned} \det\lambda &= \lambda_{m,L_c}\lambda_{s,L_n} - \lambda_{s,L_c}\lambda_{m,L_n} \\ &= \lambda_{m,L_c}\left(1-\lambda_{m,L_n}\right) - \left(1-\lambda_{m,L_c}\right)\lambda_{m,L_n} \\ &= \lambda_{m,L_c} - \lambda_{m,L_n} = \lambda_{s,L_n} - \lambda_{s,L_c}. \end{aligned}$$

Hence, assuming wlog that $\hat{L}_n = 0$, then

$$\hat{Y}_m = \frac{\lambda_{s,L_n}}{\lambda_{s,L_n} - \lambda_{s,L_c}}\hat{L}_c > \hat{L}_c > 0$$

Figure 17: Imports from China and College Enrollment Across Income Quartiles



Notes: Values on the x-axis denote different quartile ranges. Blue points denote point estimates of β^q and red dashed intervals denote 95% confidence intervals. Dependent variables denote 10 × annual change in the fraction of individuals ages 18-25 enrolled in some year of college (in % pts); $N = xx$; standard errors are clustered by state; the regression analyses are weighted by initial CZ share of national population. Control variables include the share of workers in manufatruing, the share of workers with a college education, household's wealth, the level of education of the household head, and time and division fixed effects.

and

$$\hat{Y}_s = \frac{-\lambda_{m,L_n}}{\det \lambda} \hat{L}_c < 0.$$

B Data Appendix

A College enrollment controlling for parents sector

In Section 2.3, we use PSID to show that college enrollment depends parents' wealth. The model predicts that parents' sector is also important. Unfortunately, PSID doesn't have enough information about parents' sector. In turn, we re-estimate (4) using CPS data, which containes detail information about parents' sector. Because CPS doesn't have information about households' wealth, we use parents' income as a proxy of wealth.

C Model Computation

TO BE ADDED

D Model Robustness

TO BE ADDED

E *Fixed Education* Model

TO BE ADDED