CESifo WORKING PAPERS

10333
2023
March 2023

The Decline of Routine Tasks, Education Investments, and Intergenerational Mobility

Patrick Bennett, Kai Liu, Kjell Salvanes

Impressum:

CESifo Working Papers
ISSN 2364-1428 (electronic version)
Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH
The international platform of Ludwigs-Maximilians University’s Center for Economic Studies and the ifo Institute
Poschingerstr. 5, 81679 Munich, Germany
Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
Editor: Clemens Fuest
https://www.cesifo.org/en/wp
An electronic version of the paper may be downloaded
· from the SSRN website: www.SSRN.com
· from the RePEc website: www.RePEc.org
· from the CESifo website: https://www.cesifo.org/en/wp

CESifo *Working Paper No. 10333*

The Decline of Routine Tasks, Education Investments, and Intergenerational Mobility

Abstract

How does a large structural change to the labor market affect education investments made at young ages? Exploiting differential exposure to the national decline in routine-task intensity across local labor markets, we show that the secular decline in routine tasks causes major shifts in education investments of high school students, where they invest less in vocational-trades education and increasingly invest in college education. Our results highlight that labor demand changes impact inequality in the next generation. Low-ability and low-SES students are most responsive to task-biased demand changes and, as a result, intergenerational mobility in college education increases.

Patrick Bennett
University of Liverpool / United Kingdom
Patrick.Bennett@liverpool.ac.uk

Kai Liu
Faculty of Economics
University of Cambridge / United Kingdom
kai.liu@econ.cam.ac.uk

Kjell Salvanes
NHH Norwegian School of Economics
Bergen / Norway
Kjell.Salvanes@nhh.no

March 13, 2023
The authors wish to thank participants at seminars and conferences for helpful comments and discussions. This work was partially supported by the Research Council of Norway through its Centres of Excellence Scheme, FAIR project No. 262675. Kjell G. Salvanes and Patrick Bennett gratefully acknowledge support of the Research Council of Norway, project No. 315809. Kai Liu gratefully acknowledges the support by the Upjohn Institute Early Career Research Award.

1 Introduction

The growth of professional, managerial, and technical occupations and the decline of production, operative, and clerical positions has caused fundamental changes to the task contents of jobs. As a result, more jobs require abstract (non-routine cognitive) tasks and fewer jobs require routine-intensive tasks. There is a large literature that has studied the consequences of the task-biased demand change on the labor market.[1] Yet little is known about its impact on the education investment decisions of young persons, despite the importance of their education decisions in determining future labor market outcomes and economic growth.

This paper analyzes the causal relationships between task-biased demand change and education investments. We highlight how high school students sort into different education tracks which will lead to different task concentrations in the labor market. We estimate how the *quantity* of students make different education investments in response to the task-biased demand changes. As more students increasingly invest in different types of education, we also estimate how the *quality* of marginal students changes in response to exogenous demand changes. Both quantity and quality shifts have important distributional implications for understanding the overall response to task-biased demand changes. Such changes matter for measures of equality in the education system such as intergenerational mobility (Black and Devereux, 2011; Bjorklund and Salvanes, 2011) as well as measures of equality in the labor market (Carneiro and Lee, 2011).

Using Norwegian administrative data and linking occupations to their task contents as in Autor and Dorn (2013b) and Deming (2017), we show that, similar to other developed economies, the proportion of routine-intensive tasks has declined throughout the past four decades. The decline in routine-task intensity is accompanied by a rise in the quantity of youth choosing college education, providing training in abstract-intensive tasks. At the same time, there is a decrease in the share of youth choosing vocational-trades education, providing training in relatively routine-intensive tasks.

To identify the causal impacts of the decline in routine-task intensity, we exploit differential exposure across commuting zones (CZs) to the secular change in tasks in the national labor market facing students when they choose different tracks in the first year of high school. Our task-biased labor demand shock

[1] For instance, see Dorn et al. (2009); Autor and Dorn (2013a); Cortes (2016); Edin, Evans, Graetz, Hernnäs, and Michaels (2019). Acemoglu and Autor (2011) provide an excellent review.

is measured by the predicted local change in CZ employment share of occupations with a high routine task-intensity, holding the initial composition of occupations fixed. We find that the decline in routine-task concentration decreases dropout and shifts young persons away from choosing vocational-trades education and into academic education, which leads to subsequent enrollment in college education.[2] Our results are robust to a battery of specification checks, including placebo tests that allow us to exclude any pre-existing differential trends. While results are generally similar by gender, boys shift within vocational education, away from vocational-trades towards vocational-services, at slightly higher rates relative to girls. We interpret our findings using standard models of human capital investments, and our estimates imply a positive and sizable elasticity of choice of college education with respect to expected earnings.

Shifts in education investments respond unequally depending on both student ability and parental education levels, suggesting that there are important distributional implications of the task-biased demand change. For instance, increases in college enrollment are driven by low-ability students (measured by middle school GPA before high school) and those from low-educated families. For high-ability and high-educated students, declines in routine tasks only lead to shifting into STEM fields from non-STEM fields, with overall college enrollment unchanged.[3] Therefore, task-specific demand changes shift the sorting of students into education tracks, implying that there is also quality change among youths choosing a given education investment.

Finally, we leverage parent-child linkages at the individual level to estimate on how intergenerational mobility is affected by shifting education investments in response to local demand changes. While task-biased demand changes are detrimental to the labor market prospects of the first generation, children of low-educated parents benefit from increased enrollment in college in response to such shocks. Local demand changes significantly increase intergenerational mobility in college education: the intergenerational persistence in education declines by 18% from 2003–2013 relative to the overall decline over this period. While non-college educated workers are more adversely impacted by shocks such as import competition (Autor, Dorn, and Hanson, 2013), our results show that education is an important margin of adjustment for their children.

[2]Vocational education is a prominent feature of most OECD countries: 37% of students enroll in vocational high school across the OECD (see Figure A.1). Norway is comparable with the OECD average, with slightly higher specialization in vocational education.

[3]Throughout the paper, we define STEM fields as enrollment in science, technology, engineering, math, and medicine.

This paper contributes to the literature in understanding how education investments are affected by local economic conditions, including labor market conditions (Betts and McFarland, 1995; Black, McKinnish, and Sanders, 2005), housing market (Charles, Hurst, and Notowidigdo, 2018) and openness to trade (Atkin, 2016). However, how task concentration in local labor market affects the education choices of young persons has received little attention in this literature. Using U.S. decadal census and a similar shift-share approach, Chuan and Zhang (2021) find that the rise in routinization increases college enrollment for women but not for men. We analyze a broader range of education decisions, including education tracks in high school and college majors. We also leverage the granularity of our data to examine heterogeneity of the estimates by predetermined students' ability and parental characteristics, quantifying the implication of demand-driven task changes on education inequality.

Our paper relates to a handful of papers estimating the elasticity of demand for schooling (including field of study) with respect to the expected earnings premium. While Abramitzky, Lavy, and Segev (2022) find that young adults are responsive to changes in the returns to schooling, Beffy, Fougère, and Maurel (2012) and Wiswall and Zafar (2014) find limited response in the choice of major to variation in returns across field of study. Our elasticity estimates rely on relative changes in wage premia induced by task-biased technical change, which represent a large structural change to the labor market that is likely a permanent change in most developed economies. We also show that the elasticities differ widely by students' family background and ability.

Finally, our paper also connects to another strand of literature documenting pervasive evidence that education investment is important in ensuring a good start when first entering the labor market, and initial labor market success is persistent over the life cycle (Kahn, 2010; Oreopoulos, von Wachter, and Heisz, 2012; Altonji, Kahn, and Speer, 2016; Liu, Salvanes, and Sørensen, 2016; Schwandt and von Wachter, 2019).

2 Data and Empirical Strategy

We make use of detailed Norwegian administrative data, combining data across multiple sources. First, the central population register provides information on municipality of residence, demographics, and unique personal identifiers that can be linked with other register data. We follow Gundersen and Juvkam (2013) and match municipalities to their relevant commuting zone, resulting in 160 CZs. We also link children to their parents (and parental characteristics), allowing us to assess the intergenerational importance of changes in education investments in response to changing tasks. Our primary sample focuses on cohorts born from 1987–1997.

Second, we use data from the employment register, containing detailed information on employment, pre-tax labor earnings, occupation, and industry for the entire working-age population.[4] We map a worker's detailed four-digit occupation, with 356 possible occupations, to the O*NET data following Deming (2017).[5] We are able to construct the distribution of task intensities within each CZ between 2003 and 2018. For sensitivity analysis, we also make use of the 1980 population census data, which allows us to construct changes in task-specific labor demand going back to 1980. This allows us to construct measures of task intensity for each CZ over a 20+ year period, providing a longer-run perspective on the importance of shifts in education investments in response to changing tasks.

Finally, the education register provides annual data on an individual's highest level of completed education and any ongoing study. In Norway, academic tracking begins at the start of high school, where students choose between an academic and vocational track. The academic track lasts three years and is geared towards preparing students to attend higher college-level education.[6] We focus on completion of high school across different fields—where we separate high school into academic, vocational-services, and vocational-trades degrees as in Bertrand, Mogstad, and Mountjoy (2021)—and enrollment in college education. In addition, we separate college into STEM fields—defined as science, technology, engineering, math, and medicine—and non-STEM fields. As a proxy for the "quality" of students, we also make use of the middle school GPA data, which is the sum of the final-year grades in 11 different subjects.[7]

2.1 Empirical Strategy

Our empirical strategy exploits differential exposure across CZs to the secular change in tasks in the national labor market. Our measure of changes in local labor market demand is the CZ-specific

[4] Occupational data is collected starting in 2003 and due to data limitations, occupational data on public sector workers is largely unavailable at the start of the period, when roughly one in four public sector workers have an occupation classified. While there is considerable growth in the share of jobs in the public-sector *prior* to 2000, the public sector employment share is stable throughout our sample period.

[5] See Appendix B for details.

[6] We refer to college education as any tertiary educational program after high school. Further descriptions of the available data sources and the Norwegian education system are provided in Appendix C.

[7] Appendix C.1 provides more detail on the grading system.

projected change in routine-intensive tasks between year t and initial year t_0:

$$\Delta RSH_{mt} = \sum_{j=1}^{J} \frac{L_{mjt_0}}{L_{mt_0}} \times (lnL_{jt} - lnL_{jt^0}) \times \mathbf{1}[RTI_j > RTI^{p66}] \tag{1}$$

where $\mathbf{1}[RTI_j > RTI^{p66}]$ is an indicator equal to one for an occupation j with a routine-task intensity greater than the 66$^{\text{th}}$ percentile (as in Autor and Dorn, 2013b), $lnL_{jt} - lnL_{jt^0}$ is the national growth in employment for occupation j, and the fraction $\frac{L_{mjt_0}}{L_{mt_0}}$ is the share of employment in occupation j in CZ m's total employment, as measured in the initial year $t_0 < t$.[8] The index of routine task-intensity, RTI_j, is defined by

$$RTI_j = \ln R_j - \ln M_j \tag{2}$$

where R_j and M_j are, respectively, the intensity of routine and math task input of occupation j, measured on a 0 to 10 scale as in Deming (2017). This measure is rising/falling in the relative importance of routine/math tasks within an occupation.

The projected change in routine-intensive tasks in Equation (1) corresponds to a shift-share method, which is often referred to as a Bartik shock in the literature (Bartik, 1991; Hershbein and Kahn, 2018; Autor, Dorn, and Hanson, 2019; Blair and Deming, 2020). As in Autor, Dorn, and Hanson (2013), the Bartik shock in (1) measures the predicted change in CZ employment share of occupations with a high routine task-intensity holding constant the initial composition of occupations.[9] The Bartik shock is calculated, by year, using data on the entire working population aged 18–54. We choose 2003 as the base year in most analyses, since this is the first year when the occupational data become available; Section 3.1 assesses how this choice of base year affects the results, using census data from 1980 as the base year.

We interpret ΔRSH_{mt} as local demand shocks to routine-intensive tasks conditional on a set of covariates, and provide additional tests to justify this assumption in Section 3.1. This Bartik measure of predicted changes in local task-intensity has a few advantages over actual changes in local task-intensity. Most importantly, actual changes in local task-intensity are problematic as they will reflect

[8] Since we link occupations in Norway to ONET in the U.S., systematic differences in the level of tasks between the two countries are a potential concern. In defining routine-intensive occupations by whether an occupation has a routine-task intensity above a given threshold, any systematic differences in task intensity levels become irrelevant as long as the relative ranking of occupations above/below the threshold is similar between the two countries.

[9] The level of RTI^{p66} is indicated by the dashed vertical line in Figure 1b. Results using the change in the average RTI are similar.

shocks to local labor demand as well as other CZ-specific shocks such as local fiscal shocks, which would affect both local tasks and school spending. In addition, actual task-intensity growth at the CZ level may be measured with error, while the Bartik measure allows for more precision.

Figure 1 describes the relationship between the RTI index and education investments over time.[10] As math and routine tasks growth and decline in importance respectively, the index is declining over time. Corresponding with the declining RTI index is the growth of enrollment in college education and the declining importance in vocational-trades education (panel a). Importantly, the growth of college education leads to occupations which are among the least RTI dominant (panel b). While the most common occupation group among the college educated is executive officers in administration, business, social work, and entertainment, the most common occupation group among the vocational-trades educated is metal and machinery workers.[11] Over 70% of those enrolled in college are eventually employed in occupations with a *negative* RTI; in contrast, over 75% of occupations from vocational-trades education have a *positive* RTI. As routine tasks become increasingly less in demand in the labor market, students are increasingly investing in education which is less routine dominant and decreasingly investing in vocational-trades degrees dominated by routine tasks.

In order to further understand the sources of declining routine tasks, Figure D.2 describes the growth in occupations from 2003–2015. High-skilled occupations grow considerably, driven by growth among professionals and technicians. This growth comes at the expense of declines in middle-skilled occupations such as plant operators, clerks, and trade workers. Figure E.1 describes the initial employment shares in high RTI jobs across industries and education. Consistent with the shifts in occupations, nearly 50% of manufacturing jobs are high RTI, compared to just 20% for non-manufacturing jobs. Differences by education are similar: while less than 10% of college educated workers are in high RTI jobs, over 30% of non-college educated are. As such, children from low-educated families are considerably more likely to have a parent adversely affected by local demand shocks.[12] In addition, we correlate the decline in RTI with industry compositions and automation: CZs with larger initial manufacturing shares and those that are more affected by automation see larger declines in RTI (Table E.1).

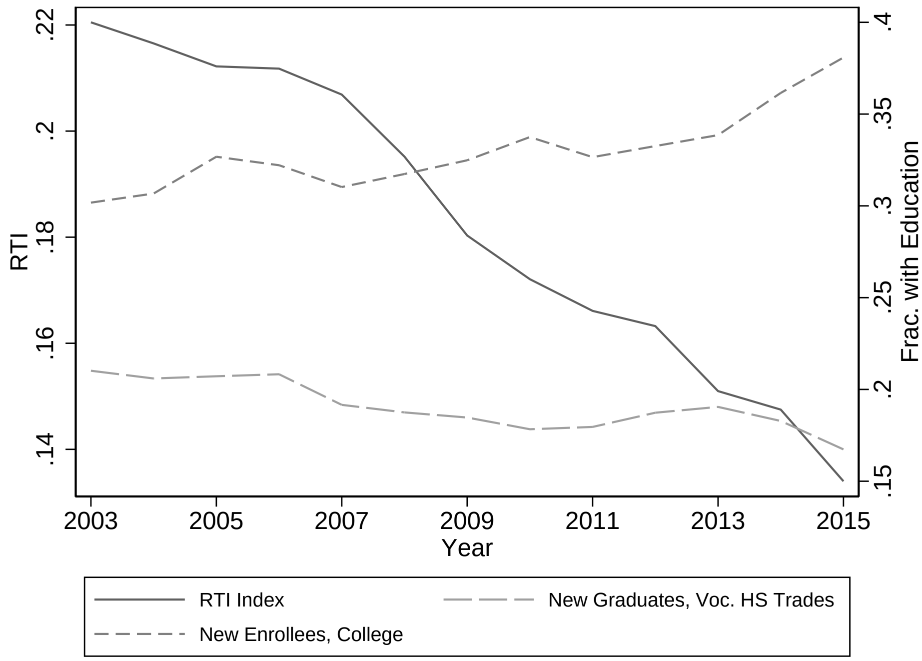
[10]Figure D.1 presents the change in RTI going back to 1980. Similar to the U.S. (Autor, Levy, and Murnane, 2003), there is a stark decline from 1980–2000 in routine relative to nonroutine (analytical) tasks.

[11]Appendix D describes common occupations for different fields in further detail.

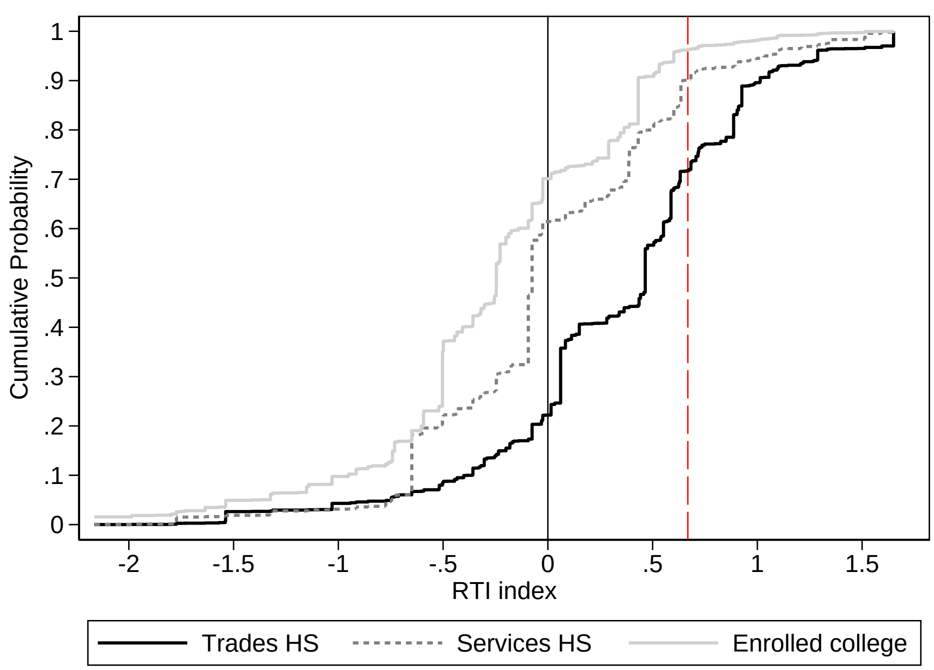
[12]Figure E.2 shows large earnings gaps between low/high RTI jobs which expand over the sample period.

Figure 1: The Relationship Between RTI Index and Education Investments

(a) RTI Index and Education of New Graduates/Enrollees Over Time



(b) RTI Index Across Fields of Study



Notes: Panel (a) plots the RTI index and growth of new graduates across fields of study. RTI index measured for all private workers aged 18–54; new graduation and enrollment in vocational-trades high school and college education measured for those aged 21. Panel (b) plots the cumulative density of RTI index across two vocational high school degrees, trades and services, and enrollment in college for those born in 1985. The dashed line corresponds to the level of RTI index where occupation is classified as high RTI. Linkage between field of study and RTI index is defined in Appendix D.

3 Demand Shocks and Education Investments

To estimate the causal effect of changes in tasks on education investment, we exploit geographic variation in the predicted changes in local task-intensity facing different cohorts using the following regression model:

$$\Delta Y_{mc} = \beta_{0c} + \beta_{1c}\Delta Z_{mc} + \boldsymbol{\beta}_{2c}'\boldsymbol{X}_m + \varepsilon_{mc} \tag{3}$$

Equation (3) is estimated separately for each of the 10 successive cohorts ($c = 1988, \ldots, 1997$). The dependent variable, ΔY_{mc}, is the difference in education investment between cohort c, who resided in CZ m at age 16, and the base cohort (the 1987 birth cohort), who resided in the same CZ at age 16.[13] ΔZ_{mc} is the predicted change in local routine-intensive tasks between cohort c and the base cohort, measured when they are at age 16 (when they are about to start high school), defined by

$$\Delta Z_{mc} = \frac{\Delta RSH_{mc+16}}{\Delta \overline{RSH}_{c+16}}, \ c + 16 \in \{2004, \ldots, 2013\} \tag{4}$$

ΔZ_{mc} corresponds to the Bartik shock, defined in Equation (1) evaluated in the year when cohort c turns age 16 ($t = c+16$) and scaled by the aggregate predicted change over the same period ($\overline{RSH}_{c+16}$). The coefficient β_{1c} correlates (between-cohort) local changes in the routine-intensive tasks with (between-cohort) local changes in education investment. Given that we measure changes in the local routine-intensive tasks (ΔZ_{mc}) at age 16, ΔZ_{mc} is pre-determined as the local demand change took place before the education decisions were made by cohort c. This has a major advantage over alternative research designs that correlate population-wide changes in education attainment with changes in tasks over calendar time, for changes in education attainment may affect local routine-task concentration either through a direct supply effect or through a demand channel, or both.[14]

Equation (3) is estimated in first-difference using successively longer time differences; the estimated parameters vary flexibly by cohort. The constant term, β_{0c}, absorbs the overall change in education in the absence of the demand shock. The coefficient β_{1c} is identified from geographic differences across CZs in the predicted changes in routine-intensive tasks, conditioning on changes at the national level.

[13] Education outcomes are measured at age 21, when most have completed high school and started to enroll in college (see Appendix C).

[14] For instance, increasing education attainment may change the task-specific labor demand at the local level as firms adapt their technological inputs in production to local skill levels (Carneiro, Liu, and Salvanes, 2023).

The regression is weighted by cohort size in CZ's in the initial year. In Section 3.2, we also estimate the same regression separately by students' ability groups and parental education groups, allowing the parameters in Equation (3) to vary flexibly across groups and removing time-invariant factors that are specific to each group.

By specifying the regression in differences, we remove CZ-level permanent characteristics that may have affected education decisions and tasks at the same time. In the regression, we additionally control for a set of CZ-level characteristics ($\boldsymbol{X}_m$)—the share of employment in manufacturing, employment-to-population ratio, the fraction of the population over 40, initial specialization in high school fields (the fractions specializing in trades and academic), and the initial specialization in college fields (the fraction specializing in STEM college)—all measured using data on the overall population from 18–54 using data just prior to the initial base year from, 2000–2002. Our key identifying assumption is that there is no pre-existing unobserved differential trend that is correlated with ΔZ_{mc}, conditional on the initial differences across CZs (X_m). In Section 3.1 we provide placebo tests for the pre-existing differential trends, finding no evidence of differential trends conditional on the CZ-level characteristics at the start of the panel.

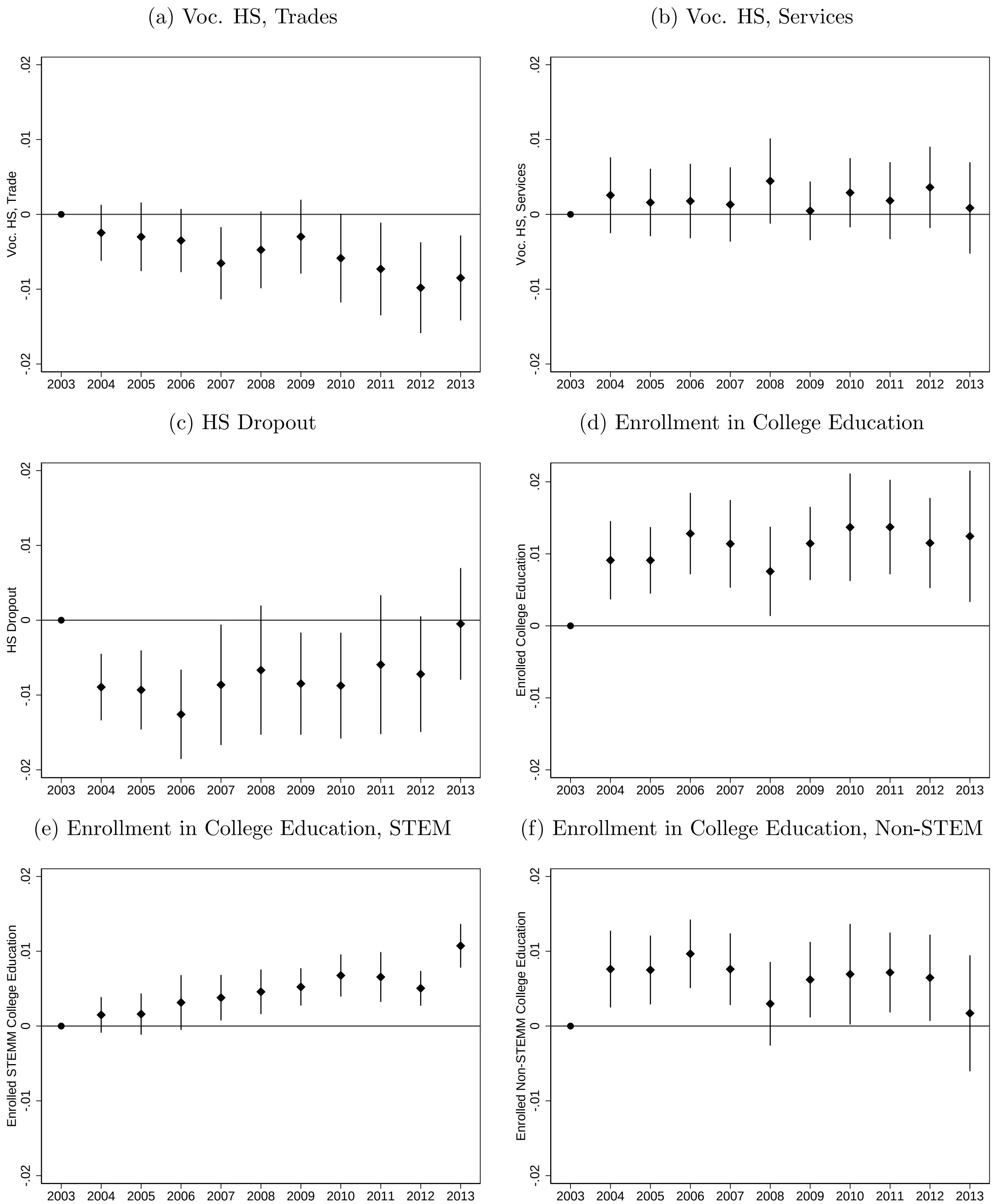
Figure 2 presents how local changes in task-intensity lead to considerable shifts in investments in education. Students shift away from investing in vocational-trades education, which are dominated by high RTI occupations and are the most exposed to changing tasks. The shift away from specialization in vocational-trades, as predicted by the average Bartik shock from 2003–2013, corresponds to 0.8 percentage point (ppt) decline, 8% relative to the average in the initial period. Within vocational high school, there is some evidence that students shift towards investing in services (panel b), though such increases are not statistically significant. Importantly, the declining importance of routine tasks leads not just to changes in specialization within high school, but also to increases in the fraction of students investing in education, as high school dropout rates are significantly lower (panel c). Students who shift away from vocational high school primarily shift towards academic high school. Indeed, changes in local demand mainly decrease dropout through a large increase in academic high school (see Figure F.1). Increases in academic high school are important, as there is a strong connection between academic high school and further investments in college education: nearly all of the 43% of the base cohort who graduate from academic high school enroll in college by 21.

Increasing investments in high school education among students affected by negative demand shocks also translate to significant increases in enrollment in college education at age 21 (panel d). Such gains correspond to a 1.2 ppt increase by 2013, a 3.3% increase, and suggest that students on the margin of shifting from vocational toward academic high school have a strong willingness to invest in higher education. Panels e & f reveal that while there is some increase in enrollment in non-STEM fields in the short-run, enrollment in STEM fields is especially large, and increases by 12% by 2013. Given the large labor market return to science, engineering, and medical fields (Altonji, Arcidiacono, and Maurel, 2016; Kirkeboen, Leuven, and Mogstad, 2016), the increase in STEM resulting from changes in demand is particularly important. While most cohorts are too young to follow enrollment to graduation, Appendix G reveals minor declines from enrollment to graduation by age 27, among cohorts for whom graduation is observable. Such a finding is crucial, as increases in college enrollment come at the expense of youth employment (Figure F.2a), and not in education, employment, or training (NEET) remains unchanged at age 21 (Figure F.2b).

Elasticities of Education with Respect to Expected Earnings In standard models of education investment (Becker, 1975; Willis and Rosen, 1979), whether an individual should acquire additional education depends on the marginal benefit of increasing lifetime earnings relative to the marginal cost, including tuition, psychic costs, and the opportunity cost of foregone earnings. In Norway, tuition at all levels of education, including college, is free, so tuition costs are negligible. As reported in the first row of Table 1, we find that the decline in routine tasks between 2003 and 2013 widens the relative gap in earnings between college-educated workers and workers who have vocational-trade education. This implies that the decline in routine tasks increases the marginal benefit of college education relative to vocational-trade education. In addition, we find that the decline in routine tasks reduces the average earnings of vocational-trade-educated workers, suggesting that the opportunity cost of college attendance also declines. Assuming that psychic costs are invariant to the local demand change, a standard human capital investment model predicts an increase in college enrollment as routine tasks decline, consistent with our findings above.

The rest of Table 1 uses the estimated responses in education investments and changes in relative earnings premia to infer the elasticities of education choice with respect to expected earnings. We assess how changes in relative earnings between those with college and vocational-trades education,

Figure 2: The Effect of Local Demand Changes on Education Investments



Notes: Figure plots estimates of β_{1c} from Equation (3). Year plotted on x-axis corresponds to the year a birth cohort faces the RTI shock at age 16 for cohorts born 1987–1997. Average values of reference group across six outcome variables measured at age 21: 11%, 11.2%, 34.5%, 38.2%, 9.0%, & 29.2% respectively. 95% confidence intervals plotted.

Table 1: The Relative Elasticity of College and Vocational-Trades Education, 2003–2013

	(1) Gap in 2003	(2) Estimated Change, Bartik 03-13	(3) % Change	(4) Relative elasticity, college & voc.-trades
Relative earnings, $ln(college) - ln(trades)$	0.063	0.010*** (0.003)	15.2%	–
Relative education, $college - trades$:	*Panel (a): overall sample*			
Overall Sample	0.273	0.025*** (0.007)	9.2%	0.61
	Panel (b): bottom & top of GPA			
GPA, Bottom	-0.095	0.030*** (0.009)	32%	2.11
GPA, Top	0.668	-0.001 (0.006)	-0.1%	-0.01
	Panel (c): high & low father's education			
Father's Education, Low	0.154	0.024** (0.009)	15.8%	1.04
Father's Education, High	0.414	0.014 (0.010)	3.5%	0.23

Notes: Standard errors reported in parentheses clustered at the commuting zone (CZ) level. ***, **, and * correspond to significance at the 1%, 5%, and 10% levels respectively. Table shows estimates of relative earnings and education between college and vocational-trades education. Column (1) presents the average gap between college & trades earnings/education prior to the Bartik shock in 2003. Column (2) estimates the impact of the Bartik shock on relative earnings/education, as specified below. Column (3) reports the percentage change from 2003–2013 due to the Bartik shock estimated in column (2). Column (4) reports the relative elasticity, dividing the percentage change in relative education by the percentage change in relative earnings. The estimation sample for relative education is cohorts born in 1987 and 1997. 7.2% of sample missing data on middle school GPA. Relative education choices between college and vocational-trades education reported in panels (a)–(c). Panel (a) reports estimates from overall sample, panel (b) reports estimates separately by student ability level, and panel (c) reports estimates separately by parental education level. High/low ability in panel (b) defined as student in the top/bottom 25% of middle school GPA distribution. High/low-educated in panel (c) defined as student whose father is college/non-college educated. Sample of 160 CZs. Estimating equation for column (2): $\Delta Y_{gmc} = \beta_{0gc} + \beta_{1c}\Delta Z_{mc} + \beta_{2c}X_m + \varepsilon_{gmc}$, where g corresponds to each of the GPA/father's education groups in panels (b) and (c). Y_{gmc} in relative earnings regression is $ln(college) - ln(trades)$, where *college* & *trades* are the average earnings of pre-tax labor earnings from all workers 18–54 who have a minimum earnings level greater than 1 pension qualifying amount in 2003 & 2013. Y_{gmc} in relative education regression is $college - trades$, where *college* & *trades* are the average fraction of students who invest in type of education in 2003 & 2013.

as caused by the local demand changes, impact the relative education investments of students at age 16. A one-unit change in the Bartik shock (corresponding to the average 10-year change) increases the relative earnings gap by 1 ppt, or 15.2% change relative to the initial earnings gap in 2003. The same increase in the Bartik shock leads to an 2.5ppt increase in the relative proportion of individuals choosing college education to vocational-trades education, or 9.2% relative to the initial education gap in 2003 (panel (a)). This implies a relative elasticity between college and vocational-trades education with respect to expected earnings at 0.61. Therefore, we find a positive and sizable elasticity of choice of education with respect to expected earnings, although the elasticities differ considerably by students' characteristics (see Section 3.2).

3.1 Validating Identifying Assumptions and Robustness Checks

We conduct several specification checks to investigate the robustness of these results. A major concern with the approach of Equation (3) is that places that are more/less affected by the change in demand may have differential trends in education prior to the shock. Figure H.1 reports results from placebo regressions, where we regress changes in education investments between the 2003 cohort and *prior* cohort (those aged 16 from 1997–2002) on the predicted (future) changes in local demand from 2003–2013, conditional on the same set of covariates X_m from Equation (3). The coefficients on the predicted changes in local demand provide a test for whether there were differential trends in education investments between areas that are more/less exposed prior to the changes in demand in the future. Figure H.1 shows that the estimated coefficients are small in magnitude and generally not significantly different from zero, suggesting that areas which are more/less affected by the change in demand are on similar trends prior to the local demand changes.

Results are also robust to alternative definitions of the Bartik shock. Figure H.2 includes a third factor in the RTI of Equation (2) to include services, which have also become increasingly important over time. Results are unchanged when excluding services, confirming that results are robust to alternative definitions of RTI. Figure H.3 examines how sensitive the Bartik demand shock is to the choice of the initial period, moving the initial period from 2003 to more than 20 years earlier, in 1980. While the figure estimates a long-run difference, results are similar: local demand shocks shift education investments away from trades education and increase college enrollment. Importantly, these long-run differences also follow students to graduation by age 30, as the estimated increases in enrollment at age 21 are nearly identical to graduation by age 30. In addition, results are robust to using the initial share of jobs in 1980, $\frac{L_{mj1980}}{L_{m1980}}$ from Equation (1), but keeping the shift in employment relative to 2003, $(lnL_{jt} - lnL_{j2003})$ (see Figure H.4). Finally, Figure H.5 reveals that results are unchanged when calculating the "leave-one-out" Bartik shock, which excludes the influence of the local CZ itself in national demand change.

To ensure that the Bartik shock represents an exogenous demand change, we show that results are robust to controlling for the effect of the expansion of the European Union in 2004 and the resulting increase in immigration of Polish and Baltic workers (Bratsberg and Raaum, 2012). Figure H.6 confirms that the increases in immigration are not driving the observed changes in education investments, and results are unchanged controlling for immigration increases. Figure H.7 shows that using a student's birth CZ produces identical results to those using a student's CZ at age 16. While parents may potentially anticipate local demand shocks and relocate in response to them, mobility responds to import competition in the U.S. with a considerable lag (Greenland, Lopresti, and McHenry, 2019). Indeed, any mobility from birth to age 16 is not fundamentally important for the results.

Figure H.8 assesses the importance of large urban areas for the baseline results. Work in urban areas has evolved differently over time (Autor, 2019), and it is important to understand how important urban areas are for the overall effects reported in Figure 2. Results excluding these large cities are similar, although the increases in college education are roughly 25–50% smaller in magnitude, suggesting that the availability of local options to invest in higher education are important as universities are overwhelmingly located in urban areas.

3.2 Unequal Responses by Student Achievement and Family Background

We assess heterogeneity of the shifts in education investments, focusing on whether investments respond differently by students' achievement (middle school GPA) and parental education. Just 5% of students in the bottom GPA quartile enroll in college, compared to 77% in the top GPA quartile. Similarly, there are large gaps in college enrollment of 24ppt between students with college/non-college educated fathers.[15]

[15] Appendix I reports results for maternal education. Results are similar when considering heterogeneity by maternal education, with slightly larger impacts on college education for both college and non-college educated families. Figures I.1

We estimate Equation (3) separately by subgroups defined by student achievement and parental education levels, removing any time-invariant factors specific to these groups. We define students as high-/low-ability if they are in the top/bottom quartile of middle school GPA in their cohort. Similarly, we use parental education as a proxy for SES, defined as whether a student's father is college educated.[16] Table 2 reveals that changes in local demand primarily impact the education investments of low-ability and low-SES students.

Focusing on differences by GPA, columns (1)–(2) and (5)–(6), reveals four key findings. First, declining investments in trades education are driven by low-ability students in the bottom quartile of the GPA distribution—who are 1.5 ppt (10%) less likely to graduate from trades degrees—with no observed change among high-ability students. Second, low-ability students shift within vocational education to invest in services degrees, which increases by 0.8 ppt (9%), with no impacts among high-ability students. Third, enrollment in college increases among low-ability students by 1.1 ppt (20%). Finally, there is an increase in STEM degrees for both high- and low-ability students. While high-ability students increasingly enroll in STEM degrees at the expense of non-STEM degrees, whose decline mirrors the increase in STEM degrees, low-ability students increasingly invest in both STEM and non-STEM degrees. Indeed, non-STEM degrees matter considerably for low-ability students, which increase by 0.7 ppt (24%).

For low-SES children, investments in trades degrees decline significantly while investment in services degrees increase significantly (panel a, column 4 and panel b, column 8 respectively). In contrast to low-ability students, dropout also decreases among low-SES students. Similar to low-ability students, these shifts in investment in high school translate into significant increases in enrollment in both STEM and non-STEM college degrees. However, in contrast to high-ability students, those from high-SES families also shift their education investments in response to changes in labor demand: investment in trades decreases significantly (panel a, column 3), while both high school dropout and college enrollment remain unchanged (panel c, column 3 and panel d, column 7 respectively). As with high-ability students, those from high-SES families also substitute away from non-STEM college to STEM college, and total college enrollment remains unchanged.

and I.2 present results separately by gender; while results are generally similar between girls and boys, boys shift away from vocational-trades to vocational-services education relatively more.

[16] Although there exists some overlap between measures of ability and SES, the correlation is far from perfect (see Appendix J.1).

Overall, low-ability and low-SES students increase enrollment in college education considerably more relative to high-ability and high-SES students.[17] This is further confirmed by the relative elasticities reported in panels (b) and (c) of Table 1: the relative elasticity between college and vocational-trades education with respect to expected earnings is 2.11 for low-ability students and close to 0 for high-ability students. Similarly, the relative elasticity of low-SES students is a few times greater than the elasticity for high-SES students (1.04 vs. 0.23). Although the demand changes are far from eliminating the large initial enrollment gaps, they lead to considerable catching up among students from more disadvantaged backgrounds.[18]

Differential Response by Ability Conditional on SES There is substantial variation among the low-educated sample by ability level, and a considerable fraction of students are either low- or high-ability (see Table K.1). Table K.2 reveals that even when conditioning on students from low-educated families, there are stark differences in the response of students on the margin by ability. Low-ability, low-SES students are those who drive the shifts in education among low-SES families, and there is little response among high-ability, low-SES students. As such, both ability and SES measures are important to understand how the quality of marginal students changes in response to local demand shocks.

4 Demand Shocks and Intergenerational Mobility in Education

Given the larger increase in enrollment among students from low-educated families, Table 3 presents how the intergenerational persistence in education is affected by labor demand changes. We measure how local demand changes affect the intergenerational persistence in college education from fathers to their children (both girls and boys) at the individual level. Equation 5 tests whether the (local) intergenerational persistence in education changes more over time in areas with larger demand shocks (ΔZ_{m2013}).[19] We leverage variation that affects the intergenerational persistence in education from

[17] Consistent with Appendix I, low-ability boys are slightly more likely to shift from trades to services, while low-ability girls are slightly more likely to enroll in college.

[18] The large increase in college attendance for low-ability students is consistent with an extended model of human capital investment where the psychic costs from college education are decreasing in students' ability (see Charles, Hurst, and Notowidigdo, 2018). Such a model implies a threshold ability beyond which students will choose college education. As the returns from college attendance become larger, this will reduce the threshold for college education and push marginally low-ability students into college.

[19] Similar approaches are taken in Pekkarinen, Uusitalo, and Kerr (2009); Bütikofer, Dalla-Zuanna, and Salvanes (2022) for intergenerational mobility in earnings.

Table 2: The Effect of Local Demand Changes on Education Investments by Ability & Parental Education, 2003–2013

	GPA		Father's Education		GPA		Father's Education	
	Top (1)	Bottom (2)	High (3)	Low (4)	Top (5)	Bottom (6)	High (7)	Low (8)
	Panel A: Voc HS, trades				*Panel B: Voc HS, services*			
point estimate, 2003-2013	-0.000	-0.015***	-0.005**	-0.007***	-0.003	0.008***	-0.001	0.004**
	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
% of mean	[-0.3]	[-9.8]	[-5.4]	[-4.8]	[-3.1]	[8.6]	[-1.7]	[3.5]
	Panel C: HS dropout				*Panel D: enrollment in college*			
point estimate, 2003-2013	0.001	-0.003	0.001	-0.004*	0.002	0.011***	0.007	0.015***
	(0.002)	(0.005)	(0.003)	(0.002)	(0.004)	(0.003)	(0.004)	(0.003)
% of mean	[1.0]	[-0.4]	[0.6]	[-1.1]	[0.2]	[19.6]	[1.3]	[5.0]
	Panel E: enrollment in college, STEM				*Panel F: enrollment in college, Non-STEM*			
point estimate, 2003-2013	0.013***	0.004**	0.017***	0.006***	-0.012***	0.007***	-0.011**	0.009***
	(0.003)	(0.002)	(0.002)	(0.001)	(0.004)	(0.003)	(0.004)	(0.003)
% of mean	[7.1]	[15.3]	[12.2]	[10.5]	[-2.0]	[23.5]	[-2.9]	[3.8]

Notes: Standard errors reported in parentheses clustered at the commuting zone (CZ) level. ***, **, and * correspond to significance at the 1%, 5%, and 10% levels respectively. Table shows estimates of β_{1c} from Equation (3). Point estimate calculated as a percent of the mean of the initial cohort reported in brackets. Estimation period is 10 year difference from 2003–2013 for cohorts born 1987 and 1997. 7.2% of sample missing data on middle school GPA. High-ability in columns (1) & (5) defined as student in the top 25% of middle school GPA distribution. Low ability in columns (2) & (6) defined as student in the bottom 25% of middle school GPA distribution. High-educated in columns (3) & (7) defined as student whose father is a college graduate. Low-educated in columns (4) & (8) defined as student whose father is non-college educated. Sample of 160 CZs. Estimating equation: $\Delta Y_{gmc} = \beta_{0gc} + \beta_{1c}\Delta Z_{mc} + \beta_{2c}X_m + \varepsilon_{gmc}$, where g corresponds to each of the GPA/father's education groups.

2003–2013 with the following linear probability model:

$$\begin{aligned} college_{imc} =& \gamma_0 + \gamma_1 college^f_{imc} + \gamma_2 1(c = 2013) + \gamma_3 college^f_{imc} \times 1(c = 2013) \\ & + \gamma_4 college^f_{imc} \times \Delta Z_{m2013} \times 1(c = 2013) + \gamma_5 \Delta Z_{m2013} \times college^f_{imc} \\ & + \gamma_6 \Delta Z_{m2013} \times 1(c = 2013) + \gamma_7 \Delta Z_{m2013} + \boldsymbol{\gamma}'_x \boldsymbol{X}_m + \varepsilon_{imc}. \end{aligned} \tag{5}$$

The pair-wise regression takes two cohorts, $c = 2003, 2013$, and estimates the change in the intergenerational persistence due to the Bartik shock, where $college_{imc}$ indicates whether child i of cohort c has enrolled in college, $college^f_{imc}$ indicates whether the child's father f has completed college, and $\boldsymbol{X}_m$ includes the same set of CZ-level characteristics as included in Equation (3). γ_1 identifies the intergenerational persistence in the base 2003 cohort, γ_2 corresponds to the overall change in college enrollment from 2003–2013, and γ_3 represents the national-level change in the intergenerational persistence in the absence of a demand shock (i.e. holding $\Delta Z_{m2013} = 0$). The triple interaction coefficient γ_4 identifies how differential exposure to the demand shock, ΔZ_{m2013}, affects the intergenerational persistence in education over time. Finally, γ_5, γ_6, and γ_7 correspond to the difference in intergenerational persistence across areas affected by ΔZ_{m2013} in the base cohort, the change in college enrollment in affected areas, and the difference in college enrollment across areas affected by ΔZ_{m2013} in the base cohort respectively. While previous regressions were estimated at the area-level, we estimate Equation (5) using individual level data and cluster the standard errors at the CZ level.

Results in Table 3 reveal that local demand shocks lead to a significant decline in the intergenerational persistence of college, or equivalently, an increase in intergenerational mobility. In the absence of the demand shock, there is an overall decline in the intergenerational persistence by 0.039 (γ_3). A one-unit change in ΔZ_{m2013} (corresponding to the national average demand shock) leads to an additional decline of intergenerational persistence by 0.007 (γ_4), or 18% decline relative to the overall decline in the absence of any demand shocks. Given the unequal responses by family background where students from low-educated families increasingly enroll in college, task-specific demand changes increase intergenerational mobility in college education.

Table 3: The Effect of Local Demand Changes on the Intergenerational Persistence in College, 2003–2013

	(1) child college
father college (γ_1)	0.273***
	(0.007)
2013 (γ_2)	0.078***
	(0.006)
father college $\times$ 2013 (γ_3)	-0.039***
	(0.008)
ΔZ_{m2013} $\times$ father college $\times$ 2013 (γ_4)	-0.007***
	(0.003)
ΔZ_{m2013} $\times$father college (γ_5)	0.008***
	(0.003)
ΔZ_{m2013} $\times$ 2013 (γ_6)	0.013***
	(0.002)
ΔZ_{m2013} (γ_7)	0.011***
	(0.004)
Constant (γ_0)	-0.076
	(0.103)
Observations, individuals	114673

Notes: Standard errors reported in parentheses clustered at the commuting zone (CZ) level. ***, **, and * correspond to significance at the 1%, 5%, and 10% levels respectively. Estimation period is 10 year difference from 2003–2013 for cohorts born 1987 and 1997. Reported observations corresponds to the number of students from these cohorts. ΔZ_m2013 measures the area-level shock from 2003-2013 as defined in Equation (4). Individual level sample of cohorts born 1987 and 1997. Estimating equation: Equation (5).

5 Conclusion

How does a large structural change to the labor market affect education investments of young persons? We show that changing job tasks, as measured by the predicted decline in the intensity of routine tasks, affect education investments decisions from high school through to college. We find that students shift away from vocational-trade high school towards college education. In addition to changes in the *quantity* of students investing in different degrees, we highlight the importance of changes in the *quality* of new graduates in the face of changes in labor demand. While education investments of boys and girls respond similarly to changes in labor demand, low-ability and low-SES students respond the most to such changes.

Although task-biased technological change has led to increasing inequality in the labor market, it levels up enrollment in college education among those yet to enter the labor market. As low-SES students overwhelmingly shift their education investments in response to changes in labor demand, they are able to close gaps in college enrollment with their more advantaged counterparts. Intergenerational mobility in college education increases in response to such changes, and children of low-educated parents increasingly enroll in college in contrast to their fathers who are negatively affected by declining demand. Indeed, the estimated elasticities of college education relative to vocational-trades with respect to expected earnings are considerably larger among low-SES students. Our findings have important distributional implications for understanding inequality in education and the labor market going forward: as young students join the labor market, both the quantity and quality of new graduates are an important factor of adjustment in understanding the long-run implications of task-biased demand change.

References

Abramitzky, R., V. Lavy, and M. Segev (2022): "The Effect of Changes in the Skill Premium on College Degree Attainment and the Choice of Major," *Journal of Labor Economics*, forthcoming.

Acemoglu, D., and D. Autor (2011): "Skills, tasks and technologies: Implications for employment and earnings," in *Handbook of labor economics*, vol. 4, pp. 1043–1171. Elsevier.

Altonji, J., P. Arcidiacono, and A. Maurel (2016): "Chapter 7 - The Analysis of Field Choice in College and Graduate School: Determinants and Wage Effects," vol. 5 of *Handbook of the Economics of Education*, pp. 305–396. Elsevier.

Altonji, J. G., L. B. Kahn, and J. D. Speer (2016): "Cashier or consultant? Entry labor market conditions, field of study, and career success," *Journal of Labor Economics*, 34(S1), S361–S401.

Atkin, D. (2016): "Endogenous skill acquisition and export manufacturing in Mexico," *American Economic Review*, 106(8), 2046–2085.

Autor, D., and D. Dorn (2013a): "The growth of low-skill service jobs and the polarization of the US labor market," *American economic review*, 103(5), 1553–97.

Autor, D., D. Dorn, and G. Hanson (2019): "When Work Disappears: Manufacturing Decline and the Falling Marriage Market Value of Young Men," *American Economic Review: Insights*, 1(2), 161–78.

Autor, D., D. Dorn, and G. H. Hanson (2013): "The China syndrome: Local labor market effects of import competition in the United States," *The American Economic Review*, 103(6), 2121–2168.

Autor, D. H. (2019): "Work of the Past, Work of the Future," *AEA Papers and Proceedings*, 109, 1–32.

Autor, D. H., and D. Dorn (2013b): "The Growth of Low-Skill Service Jobs and the Polarization of the US Labor Market," *American Economic Review*, 103(5), 1553–97.

Autor, D. H., F. Levy, and R. J. Murnane (2003): "The Skill Content of Recent Technological Change: An Empirical Exploration*," *The Quarterly Journal of Economics*, 118(4), 1279–1333.

Bartik, T. J. (1991): "Who benefits from state and local economic development policies?," .

Becker, G. S. (1975): *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education, Second Edition*. NBER.

Beffy, M., D. Fougère, and A. Maurel (2012): "Choosing the Field of Study in Postsecondary Education: Do Expected Earnings Matter?," *The Review of Economics and Statistics*, 94(1), 334–347.

Bertrand, M., M. Mogstad, and J. Mountjoy (2021): "Improving Educational Pathways to Social Mobility: Evidence from Norway's Reform 94," *Journal of Labor Economics*, 39(4), 965–1010.

Betts, J. R., and L. L. McFarland (1995): "Safe port in a storm: The impact of labor market conditions on community college enrollments," *Journal of Human resources*, pp. 741–765.

Bjorklund, A., and K. G. Salvanes (2011): "Education and Family Background: Mechanisms and Policies," vol. 3, chap. 03, pp. 201–247. Elsevier, 1 edn.

Black, D. A., T. G. McKinnish, and S. G. Sanders (2005): "Tight labor markets and the demand for education: Evidence from the coal boom and bust," *ILR Review*, 59(1), 3–16.

Black, S., and P. Devereux (2011): "Recent Developments in Intergenerational Mobility," *Handbook of Labor Economics*, 4, 1487–1541.

Blair, P. Q., and D. J. Deming (2020): "Structural Increases in Demand for Skill after the Great Recession," *AEA Papers and Proceedings*, 110, 362–65.

Bratsberg, B., and O. Raaum (2012): "Immigration and Wages: Evidence from Construction," *The Economic Journal*, 122(565), 1177–1205.

Bütikofer, A., A. Dalla-Zuanna, and K. G. Salvanes (2022): "Breaking the Links: Natural Resource Booms and Intergenerational Mobility," *The Review of Economics and Statistics*, pp. 1–45.

Carneiro, P., and S. Lee (2011): "Trends in Quality-Adjusted Skill Premia in the United States, 1960-2000," *American Economic Review*, 101(6), 2309–49.

Carneiro, P., K. Liu, and K. G. Salvanes (2023): "The supply of skill and endogenous technical change: evidence from a college expansion reform," *Journal of the European Economic Association*, 21(1).

Charles, K. K., E. Hurst, and M. J. Notowidigdo (2018): "Housing Booms and Busts, Labor Market Opportunities, and College Attendance," *American Economic Review*, 108(10), 2947–94.

Chuan, A., and W. Zhang (2021): "Non-College Occupations, Workplace Routinization, and the Gender Gap in College Enrollment," Discussion paper, Faculty of Economics, University of Cambridge.

Cortes, G. M. (2016): "Where have the middle-wage workers gone? A study of polarization using panel data," *Journal of Labor Economics*, 34(1), 63–105.

Deming, D. J. (2017): "The Growing Importance of Social Skills in the Labor Market," *The Quarterly Journal of Economics*, 132(4), 1593–1640.

Dorn, D., et al. (2009): "This job is" getting old": Measuring changes in job opportunities using occupational age structure," *American Economic Review*, 99(2), 45–51.

Edin, P.-A., T. Evans, G. Graetz, S. Hernnäs, and G. Michaels (2019): "When machines replace people: individual consequences of occupational decline," Discussion paper, Centre for Economic Performance, LSE.

Greenland, A., J. Lopresti, and P. McHenry (2019): "Import Competition and Internal Migration," *The Review of Economics and Statistics*, 101(1), 44–59.

Gundersen, F., and D. Juvkam (2013): "Inndelinger i senterstruktur, sentralitet og BA-regioner," NIBR-rapport 2013:1, Norsk institutt for by- of regionforskning.

Hershbein, B., and L. B. Kahn (2018): "Do Recessions Accelerate Routine-Biased Technological Change? Evidence from Vacancy Postings," *American Economic Review*, 108(7), 1737–72.

Kahn, L. B. (2010): "The long-term labor market consequences of graduating from college in a bad economy," *Labour Economics*, 17(2), 303 – 316.

Kirkeboen, L. J., E. Leuven, and M. Mogstad (2016): "Field of Study, Earnings, and Self-Selection," *The Quarterly Journal of Economics*, 131(3), 1057–1111.

Liu, K., K. G. Salvanes, and E. Ø. Sørensen (2016): "Good skills in bad times: Cyclical skill mismatch and the long-term effects of graduating in a recession," *European Economic Review*, 84, 3 – 17, European Labor Market Issues.

Oreopoulos, P., T. von Wachter, and A. Heisz (2012): "The Short- and Long-Term Career Effects of Graduating in a Recession," *American Economic Journal: Applied Economics*, 4(1), 1–29.

Pekkarinen, T., R. Uusitalo, and S. Kerr (2009): "School tracking and intergenerational income mobility: Evidence from the Finnish comprehensive school reform," *Journal of Public Economics*, 93(7), 965–973.

Schwandt, H., and T. von Wachter (2019): "Unlucky Cohorts: Estimating the Long-Term Effects of Entering the Labor Market in a Recession in Large Cross-Sectional Data Sets," *Journal of Labor Economics*, 37(S1), S161–S198.

Willis, R. J., and S. Rosen (1979): "Education and self-selection," *Journal of political Economy*, 87(5, Part 2), S7–S36.

Wiswall, M., and B. Zafar (2014): "Determinants of College Major Choice: Identification using an Information Experiment," *The Review of Economic Studies*, 82(2), 791–824.

The Decline of Routine Tasks, Education Investments, and Intergenerational Mobility

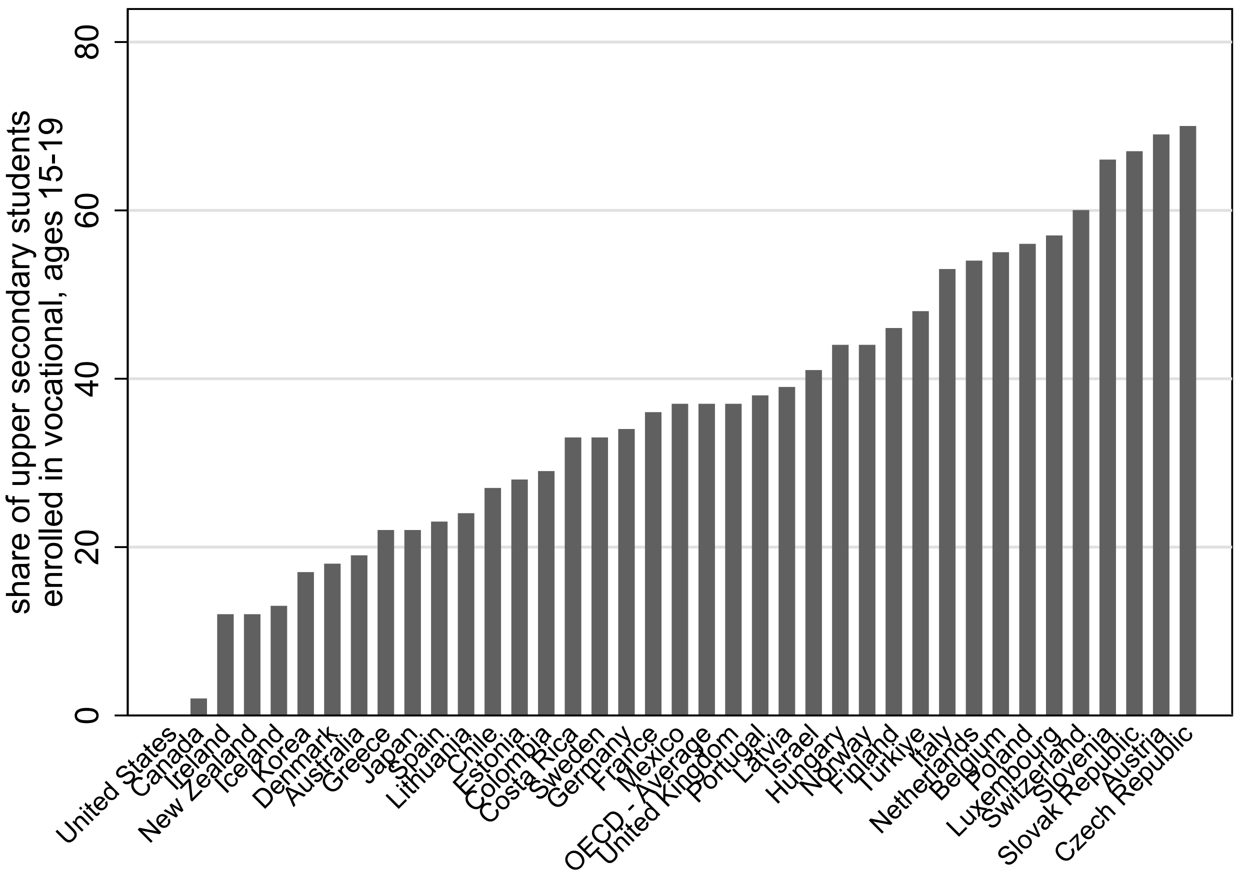
Online Appendix

Patrick Bennett* Kai Liu† Kjell Salvanes‡

*University of Liverpool. Email: Patrick.Bennett@liverpool.ac.uk
†Faculty of Economics, University of Cambridge.Email: kai.liu@econ.cam.ac.uk
‡Norwegian School of Economics. Email: Kjell.Salvanes@nhh.no

A Vocational Education Across the OECD

Figure A.1: Enrollment Among Students 15–19 in Vocational Education, 2019



Notes: Figure plots fraction of students aged 15–19 enrolled in upper secondary education who are enrolled in vocational education. OECD data defines general and vocational education for the sample of OECD countries in 2019. Data source: "Enrolment by gender, programme orientation, mode of study and type of institution" from OECD "Education at a Glance". OECD average: 37%.

B Norwegian Register Data: Additional Details

The papers uses Norwegian Register data from 2003–2018, combining data from across multiple registers. The data covers all Norwegian residents with 100% coverage.

Employment Data, Occupational Data, & Occupational Classification System Employment status is measured in the third week of November. The employment data covers all residents aged 16–74. When calculating the Bartik measures, we focus on workers aged 18–54. If an individual has multiple jobs, we focus on an individual's primary job. Due to data limitations, we focus on private sector occupations as public sector occupations are not well measured at the start of the data period.

Occupations are measured according to the STYRK1998 (Standard for Yrkeklassifisering, Norwegian standard of occupational classification) classification created by Statistics Norway. Such classification closely follows the European classification system ISCO-88 (European International Standard Classification of Occupations 1988), with some very minor differences to accommodate mior differences in structure of work. There are 356 possible occupations in the STYRK1998 classification standard.

We match occupations in the Norwegian classification system to measures of task intensity as follows. We extract raw O*NET data from O*NET 2000, and follow Deming (2017) in measuring tasks. In our primary specification, which measures $RTI_j = lnR_j - lnM_j$ for each occupation j, we make use of data on tasks for routine and math respectively. As in Deming (2017), routine tasks are measured by responses to the following questions: (i) the level of automation of this job and (ii) how important is repeating the same physical activities (e.g., key entry) or mental activities (e.g., checking entries in a ledger) over and over, without stopping, to performing this job. Math tasks are measured by responses to the following questions: (i) the ability to understand and organize a problem and then to select a mathematical method or formula to solve the problem; (ii) knowledge of numbers, their operations, and interrelationships including arithmetic, algebra, geometry, calculus, statistics, and their applications; and (iii) using mathematics to solve problems. In a robustness check, we include service tasks into this measure of RTI_j. Service tasks are measured by responses to the following questions: (i) providing assistance or personal care to others and (ii) actively looking for ways to help people.

As the values measured in O*NET have no inherent meaning, these values are rescaled to have the range of 0–10 as in Deming (2017), where 10 is the occupation with the highest task intensity and 0 is the occupation with the lowest task intensity. This O*NET data provides measures of tasks for each 6 digit SOC occupation.

To match Norwegian occupations to tasks using O*NET data on the task intensity of occupations in the US, we develop a linkage between the Norwegian occupation standard and the US Standard Occupational Classification (SOC). The mapping proceeds as follows. First, 4 digit occupations in the Norwegian standard are matched manually to the closest 6 digit occupation in the SOC.[1] Direct matches where 1 Norwegian occupation matches to 1 US occupation represent 60% of occupations. This is due to the fact that the US system is much more detailed than the Norwegian system: while there are 356 unique occupations in the Norwegian standard, there exist 821 unique occupations in the US standard.

Second, all occupations which do not have one-to-one matches are matched to multiple occupations in the US standard. One-to-two matches represent 25% of occupations in the Norwegian standard. One-to-three matches represent another 7%. In practice, when one Norwegian occupation maps to multiple occupations in the US SOC, these occupations often fall within the same group in the SOC standard. For occupations in the Norwegian standard which map to multiple occupations in the US standard, the average of the US occupations is taken and assigned to the unique Norwegian occupation.

The three occupations in the Norwegian system with the highest routine intensity are Sewing-machine operators, Stenographers and typists, and Shoemaking- and related machine operators. For math intensity, the three highest ranked occupations are Mathematicians and related professionals, Physicists and astronomers, and Chemical engineers.

Education Data Data on education is extracted from the education register. Such data is high-quality, and schools have a legal mandate to report any information on student enrollment and graduation to Statistics Norway. The data includes information on the exact qualification attained including information on field of study. Additionally, any ongoing education is also recorded for each student, including information on field of study. The completion of educational qualifications and ongoing student status are measured at the start of October.

[1] Matches are created based on the description of tasks in both standards, as well as relevant occupation titles.

Income Data From the tax and earnings register, we extract data on annual income. The measure of income comprises total labour income, including any income earned from self-employment, as well as any taxable benefits received during the year including parental leave, unemployment, and sickness benefits.

1980 Census Data Data from the 1980 census has near 100% coverage of all resident in Norway at the start of November in the census year. Employment status is measured for the 12 months preceding the census. Occupations in the 1980 census are classified according to NYK1965 (Nordisk Yrkeklassifisering-1965, Nordic Classification of Occupations), a measure which closely follows the European ISCO-58 standard. Using a crosswalk, we match occupations in the NYK1965 standard to the nearest possible occupation using the STYRK1998 standard described above.

C The Norwegian education system

The Norwegian education system consists of four levels, primary school (grades 1–7), middle school or lower secondary school (grades 8–10), high school or upper secondary school (three years), and then higher education. Norwegian compulsory education starts at age six, lasts for 10 years and consists of primary school and lower secondary school. Norwegian municipalities operate schools to provide compulsory education, and the vast majority (98%) of pupils attend public, local schools during compulsory schooling. At the elementary school level, all pupils are allocated to schools based on fixed school catchment areas within municipalities. With the exception of some religious schools and schools using specialized pedagogic principles, parents are not able to choose the school to which their children are sent (except by moving to a different neighborhood). There is a direct link between elementary school attendance and attendance at middle or lower secondary schools (ages 13–16/grades 8–10), in that elementary schools feed directly into lower secondary schools. In many cases, primary and lower secondary schools are also integrated.

The high schools have two main tracks, vocational and academic. High schools are administered at the county level (above the level of municipalities) and attendance is not mandatory, although since the early 1990s everybody graduating from middle schools has been guaranteed a slot in high school. Admissions procedures differ across counties for upper secondary schools. In some counties, pupils can freely choose schools, while in others children are allocated to schools based on well-defined catchment areas, or high school zones. Within schools, there is no systematic sorting of students into classes.

About 95% of students moving into high school enroll in the year they finish compulsory education. About 45% enroll in the academic track, which qualifies for higher education. The rest of the students enroll in the vocational track, and there are several subject fields for this track. There is an option also for students coming from the vocational track to enroll in university, but that requires some extra coursework. Admission at different universities and in different majors at universities is based on high school GPA. This is a combination of non-blind grading by local teachers and the results of the final-year exams, which are prepared centrally by the Directorate for Education (a branch of the Ministry of Education) and are subject to blind grading. The high school GPA is not normalized at the school level.

C.1 Teacher grading and exam grading at middle school (Middle school GPA)

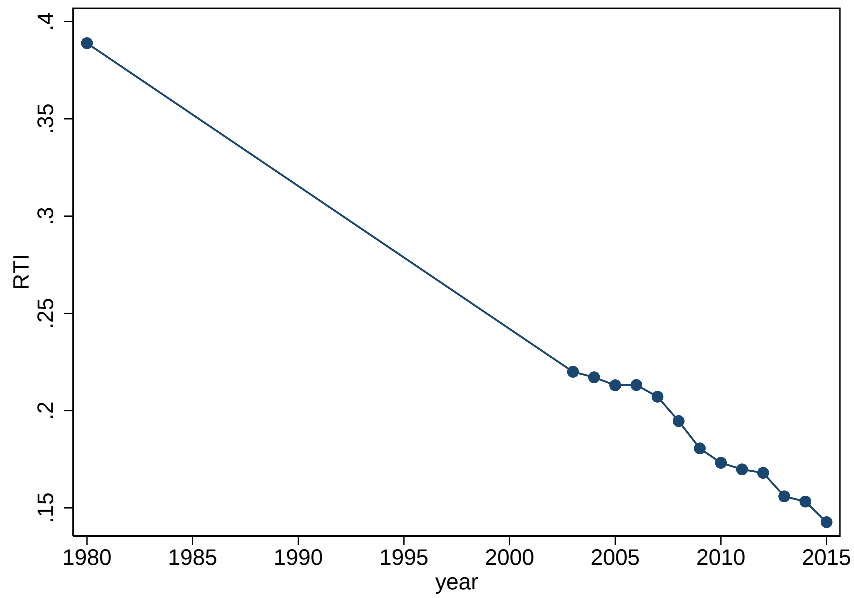
At the end of middle school, students are evaluated both non-anonymously by their teachers for 11 subjects taught in school, and in addition anonymously in 2 nationally administered exit exams, which are graded by external examiners (who are not students' teachers). The subjects for the national exit exams are randomly selected for each student among the 11 subjects in which they are also evaluated by their teachers. The assessment for Norwegian and English consists of both oral and written exams. For the rest of the subjects, the assessment consists of only written exams. In each assessment, the grade ranges between 1 and 6. The final grade of a subject is determined by a simple average between the grades by the teacher and grades from the national exam in the final year, if present. The middle school GPA is not standardized at the school level so they are not grading to the curve.

The final-year middle school GPA used by post-reform high school admission is the sum of final grades across 11 subjects, for students who had grades in at least 3 subjects, hence it ranges between 3 and 66 (i.e. 6×11). Note that the algorithm for calculating the final-year GPA changed in the school year 2006/2007. Instead of summing up the grades in 11 subject, the final-year GPA is determined by first taking a simple average across all subjects and then multiplied by 10.

Grading principles are set by the Education Act of 1998 ("Opplæringslova"). In the Prescript to the Education Act of 1998 (Forskrift til opplæringslova) it is stated that teacher evaluations are to be based on the degree to which students have achieved the competence goals stated by the subject-specific centrally set “Learning goals,” which are stated in each topic. For each subject, the final teacher evaluation grade is given in April and is set based on the performance in the final year of middle school. Notably, it is specifically stated that student behavior (“orden og oppførsel”) is not to be reflected in grading, and (of course) that student background should not count in grading (“Prescript to Education Act”). Effort is allowed to be included in grading in gymnastics. Teacher grades are given *before* the grading of national exams, and hence teachers are not aware of the student’s national exam score at the time when teacher assessment is given.

D Linking Fields of Study to Tasks

Figure D.1: Change in RTI from 1980–2015



Notes: Figure plots the RTI index measured for all private workers aged 18–54 from 1980–2015.

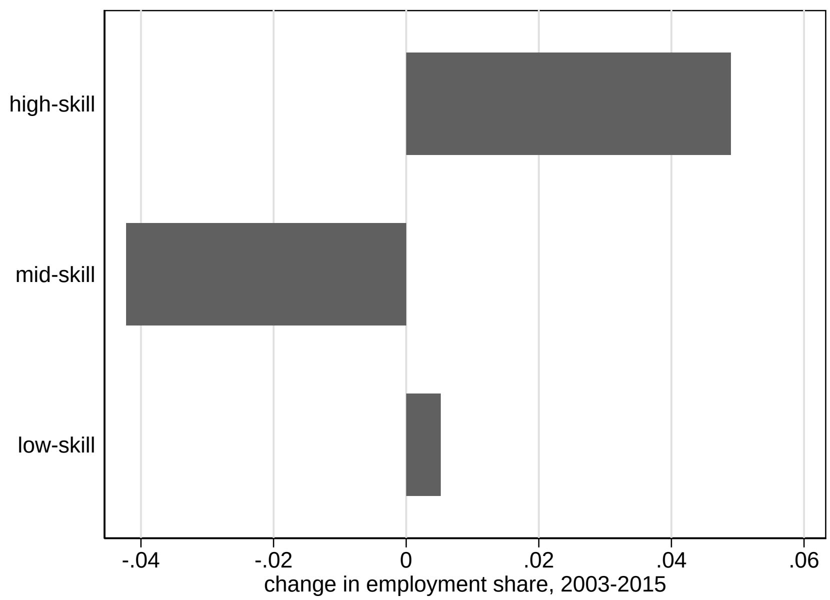
In order to measure the changes in tasks as predicted by shifts in educational investments, we create a measure of RTI for each degree as follows. First, we use data on the 1985 birth cohort, those who are aged 16 in 2001 and before our sample period. Second, we match their initial field of study at age 21—(i) high school dropout, (ii) vocational-trades, (iii) vocational-services, (iv) academic, (v) enrolled in STEM, and (vi) enrolled in non-STEM—to the occupation which they are employed in at age 30. While high school dropouts may return to graduate from education between 21–30 (see Bennett et al., 2020, for details), we measure only their initial educational choices at age 21. Similarly, those enrolled in STEM/non-STEM college may not necessarily graduate by age 30. We create a measure of tasks for each of these 6 degrees by taking the median measure of RTI across all the occupations which people in these different education levels perform. Table D.1 reports the three most common fields of study across different levels of education.

Table D.1: Most Common Occupations Among Different Fields of Study

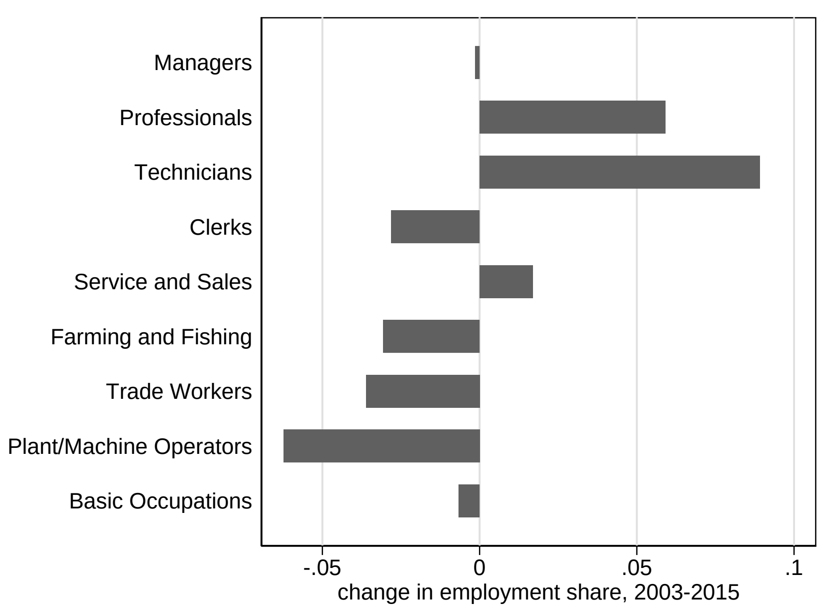
Rank:	Level of education:
	High School Dropout
1	Personal care and related workers (9.8%)
2	Salespersons and demonstrators (7%)
3	Building frame and related trades (2.6%)
	Vocational-Trades
1	Building frame and related trades (11%)
2	Engineering science technicians (9.9%)
3	Electricians, electrical, and electronic (9.8%)
	Vocational-Services
1	Personal care and related workers (24.1%)
2	Salespersons and demonstrators (8.7%)
3	Housekeeping and restaurant service (5.1%)
	College, STEM
1	Engineering science technicians (15.5%)
2	Architects and engineers (13.4%)
3	Health professionals (12.2%)
	College, non-STEM
1	Nursery and registered nurses for mentally challenged (8.2%)
2	Primary education teaching (7.7%)
3	Finance and sales associates (6.5%)

Figure D.2: Change in Occupational Employment Shares, 2003–2015

(a) Skill Groupings as in Autor (2019)



(b) Detailed 1-digit Occupations



Notes: Figure plots the change in the employment share of different occupations. Panel a groups occupations by skill as in Autor (2019), while panel b reports 1 digit occupation groupings. High-skill corresponds to Managers, Professionals, and Technicians. Mid-skill corresponds to Clerks, Trade Workers, and Plant/Machine Operators. Low-skill corresponds to Basic Occupations and Service and Sales.

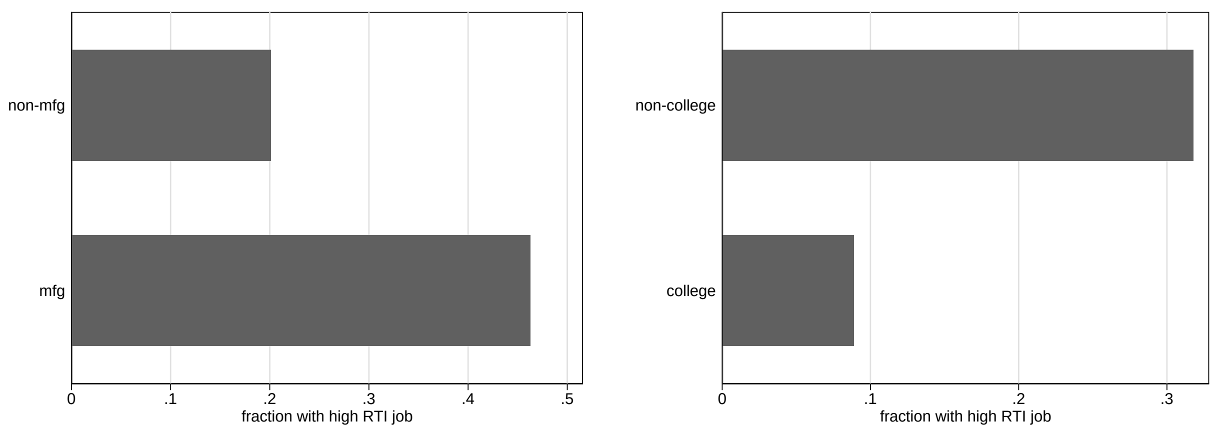
E What are High RTI Jobs and What Correlates with Their Decline?

Figure E.1 plots the fraction of jobs which are classified as high RTI occupations across different industries (panel a) and education levels (panel b). Manufacturing industries are dominated by high RTI jobs, as nearly 50% of jobs in manufacturing are high RTI occupations. In contrast, just 20% of non-manufacturing jobs are high RTI. As with manufacturing industries, work among non-college educated is dominated by routine occupations, as over 30% of these jobs are high RTI comapred to less than 10% of college jobs.

Figure E.1: Employment Shares in high RTI Jobs by Industry and Education

(a) Manufacturing/Non-manufacturing

(b) College/Non-college



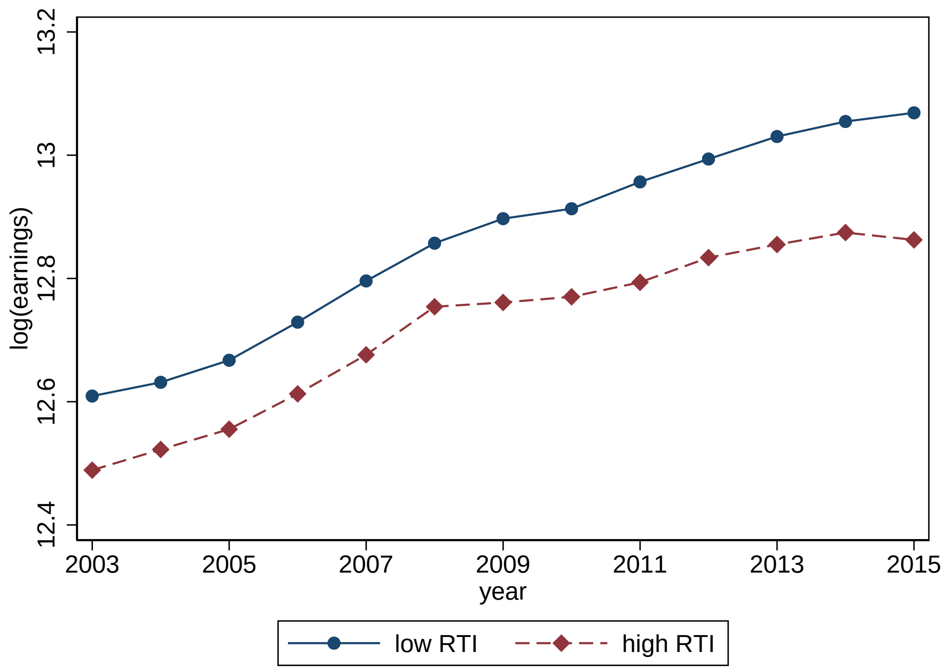
Notes: Figure plots the employment shares of high RTI jobs separately by industry (panel a) and education (panel b). Employment shares calculated for all workers aged 18–54 in the base year 2003. High RTI defined as in Section 2.1.

Figure E.2 plots the average earnings of workers employed in high/low RTI jobs from 2003–2015. In the initial year 2003, workers employed in low RTI occupations have higher earnings, a gap which roughly doubles by 2015.

Table E.1 reports the factors which are correlated with the change in the RTI index over different time periods. Time periods are from 2003–2015. Initial manufacturing share (column 1) is strongly correlated with declining routine task intensity. The negative sign suggests that areas with higher manufacturing specialization experience significantly stronger declines in routine tasks.

Automation is also significantly correlated with the change in the RTI index from 2003–2015 (column 3). The negative sign suggests that areas with more automation, measured as industrial robots per

Figure E.2: Earnings Growth over Sample Period by low and high RTI Occupations



Notes: Figure plots the average log of annual labor earnings for all workers aged 18–54 from 2003–2015. High RTI defined as in Section 2.1.

1000 workers in Norway, see larger decreases in routine task specialization.

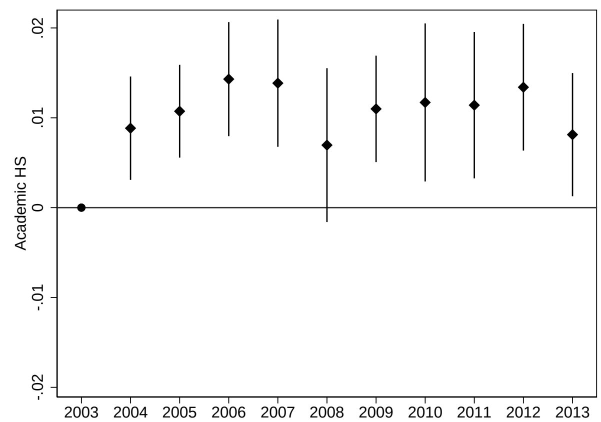
Table E.1: The Correlates with Changing Routine Task Intensity

	(1) Δ RTI, 03–15	(2) Δ RTI, 03–15	(3) Δ RTI, 03–15
initial manufacturing share, 2003	-0.171***		
	(0.050)		
Δ mfg. share		0.249	
		(0.160)	
Δ industrial robots			-0.003***
			(0.001)
Constant	-0.013**	-0.028***	-0.014**
	(0.006)	(0.006)	(0.005)
N	160	160	160

Notes: Table reports estimates from regressing the change in the RTI index over different time period on different factors reported in the table. Column (1) measures the initial fraction of jobs employed in manufacturing in 2003. Column (2) measures the change in the manufacturing share from 2003–2015. Column (3) measures the change in industrial robots from 2003–2015, the number of robots per 1000 workers allocating robots to each CZ in Norway using their initial industry share. ***, **, and * correspond to significance at the 1%, 5%, and 10% levels respectively.

F The Impact of Local Demand Shocks on Academic High School and Labor Market Outcomes at Age 21

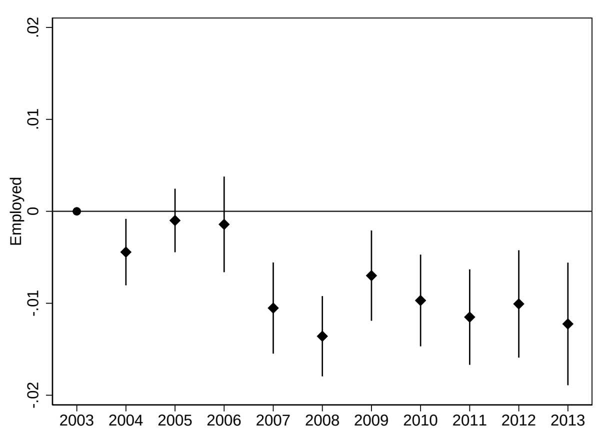
Figure F.1: The Effect of Local Demand Shocks on Academic High School



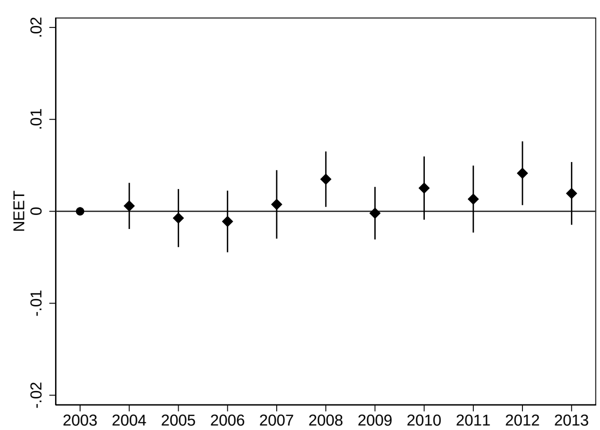
Notes: Figure plots estimates of β_{1c} from equation (3). Year plotted on x-axis corresponds to the year a birth cohort faces the RTI shock at age 16. Outcome variable: graduation from academic high school at age 21. Coefficients are scaled by average change in the Bartik shock in each year. 95% confidence intervals plotted.

Figure F.2: The Effect of Declining Routine Task Intensity on Labor Market Outcomes at Age 21

(a) Employed



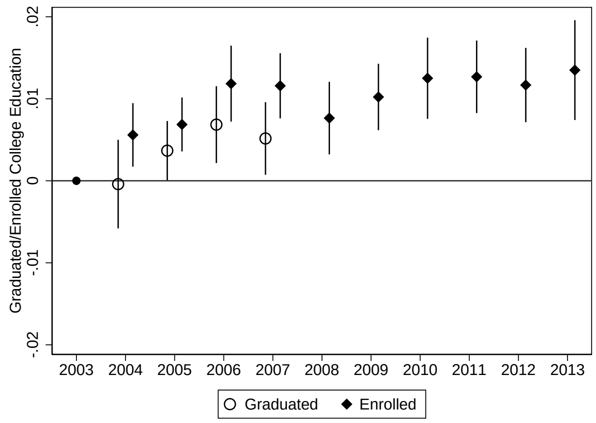
(b) NEET



Notes: Figure plots estimates of β_{1c} from equation (3). Year plotted on x-axis corresponds to the year a birth cohort faces the RTI shock at age 16. Outcome variables: employment (panel a) and not in education, employment, or training (panel b) at age 21. Coefficients are scaled by average change in the Bartik shock in each year. 95% confidence intervals plotted.

G Graduation from Higher Education by Age 27

Figure G.1: The Effect of Declining Routine Task Intensity on Graduation from Higher Education by Age 27, By Ability



Notes: Figure plots estimates of β_{1c} from equation (3). Year plotted on x-axis corresponds to the year a birth cohort faces the RTI shock at age 16. Outcome variables: graduation from higher education at age 27 and enrolled in higher education at age 27. Coefficients are scaled by average change in the Bartik shock in each year. 95% confidence intervals plotted.

H Robustness

Here we address numerous challenges to the Bartik identification. We examine the sensitivity of the results to the definition of key variables, sample selection, different measures of the Bartik shock, and additional control variables. In addition, we assess whether places which are more/less affected by the change in demand may have differential trends in education prior to the shock.

First, Figure H.2 includes a third factor in the RTI index, altering equation (2) to include services. While routine and mathematical tasks are important, services have also changed considerably, becoming more prominent in the labor market over time.

Second, Figure H.3 examines how sensitive the Bartik demand shock is to the choice of the initial period, moving the initial period from 2003 to over 20 years earlier in 1980. The exercise establishes the robustness of the results using a change in demand measured from 1980–2004, making use of the 1980 census data to understand how a longer time horizon, as well as a change of the initial period from 2003 to 1980, affects the results. That is, Figure H.3 changes the *share* of initial jobs from 2003 to 1980 and also changes the *shift* of national changes in the composition of jobs from $2003 - -t$ for $t = 2004, ...2013$ to 1980–2004. In addition, Figure H.4 examines the robustness of the results to to using the initial share of jobs in 1980, that is, changing only the *share* of initial jobs from 2003 to 1980 ($\frac{L_{mj1980}}{L_{m1980}}$ from equation (1)). By only using this initial share in 1980, the *shift* in employment remains relative to 2003, i.e. $(lnL_{jt} - lnL_{j2003})$.

Third, Figure H.8 assesses the importance of large urban areas for the baseline results. Large urban areas are five major cities in Norway, Oslo, Bergen, Stavanger, Trondheim, Kristiansand, and Tromsø. Figure H.8 excludes these 5 CZs from the estimation sample, reducing the sample size from 160 to 155. Doing so assesses the importance of urban areas for the results, but also tests how important local opportunities for higher education are as universities are overwhelmingly located in these large urban areas.

Fourth, Figure H.5 examines the robustness of the results to calculating the Bartik shock as a "leave-one-out" approach. Doing so excludes the influence of the local CZ itself in national changes in demand, which creates a shift measure of employment which is arguably more exogenous as the shift in the local area itself is endogenous.

Fifth, Figure H.7 changes the area of residence from where the student resides from age 16 to using the area of birth. Roughly 10% of those who have a CZ defined at age 16 do not have data on CZ of birth. Such a sample restriction disproportionately excludes migrants from the sample as the cannot have a CZ of birth in Norway by definition.

Sixth, Figure H.6 designs a robustness check to account for the expansion of the European Union in 2004. Following the inclusion of additional states into the European Union, there was a large influx of Polish and Baltic workers who immigrated to Norway to work, primarily, in unlicensed construction jobs (Bratsberg and Raaum, 2012). This expansion was a large shock for the Norwegian labor market, and given that the timing coincides with our sample period, it is important to exclude the confounding influence of changes in immigration at the local level, which could also potentially affect educational investments.

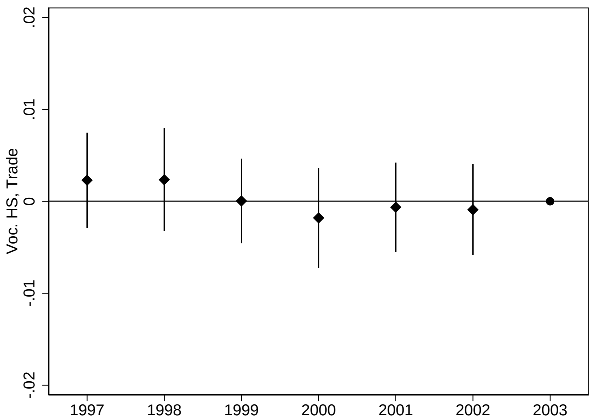
Seventh, Figure I.1 and I.2 presents results estimated at the area-level separately by females and males respectively. While results for higher education are similar, women dropout relatively less compared to men, while men shift away from vocational-trades to vocational-services relatively more than women.

Finally, Figure H.1 performs a placebo regression, asking whether education is already changing prior to the demand shock in areas that will be affected in the future. A concern with the Bartik approach of equation (3) is that places which are more/less affected by the change in demand may have differential trends in education prior to the shock. We perform this placebo regression by regressing changes in local demand from 2003–2013 on the change in education of cohorts prior to the change. We use cohorts who are aged 16 from 1997–2002 and measure the change in education between them and the 2003 birth cohort. By doing so, we ask whether there are differential trends in education between areas that are more/less exposed prior to the changes in demand.

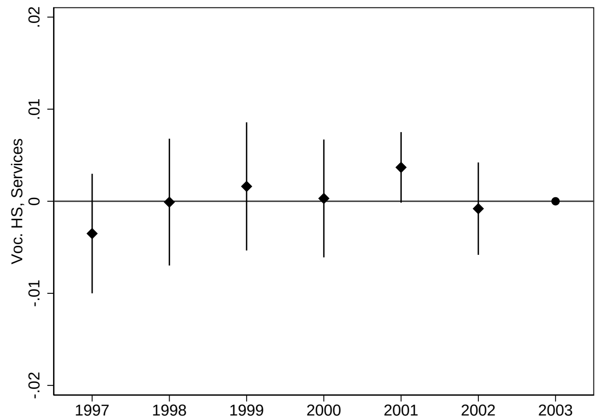
H.1 Examining the Importance of Diverging Trends Prior to Bartik Period

Figure H.1: Placebo Regression Estimating Trends in Education Prior to Bartik Shock Period

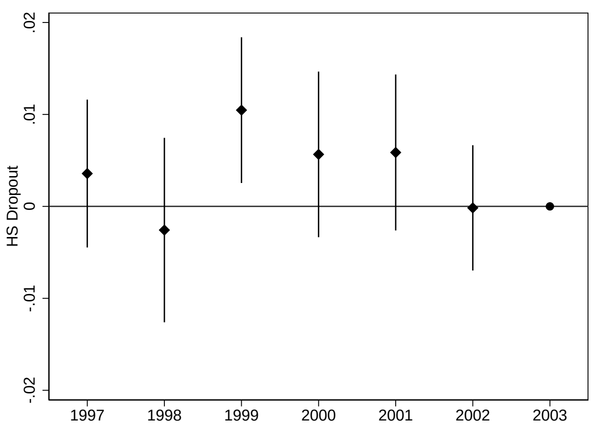
(a) Voc. HS, Trades



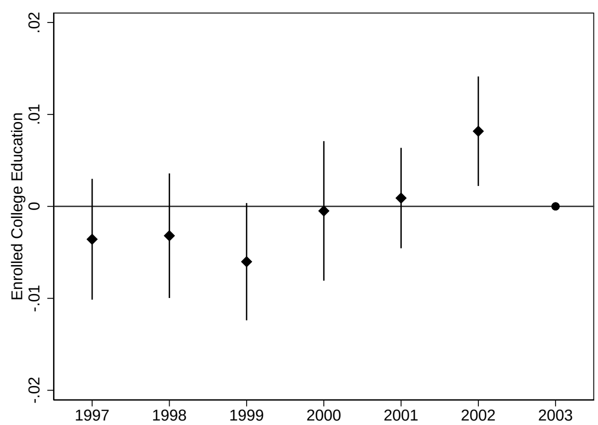
(b) Voc. HS, Services



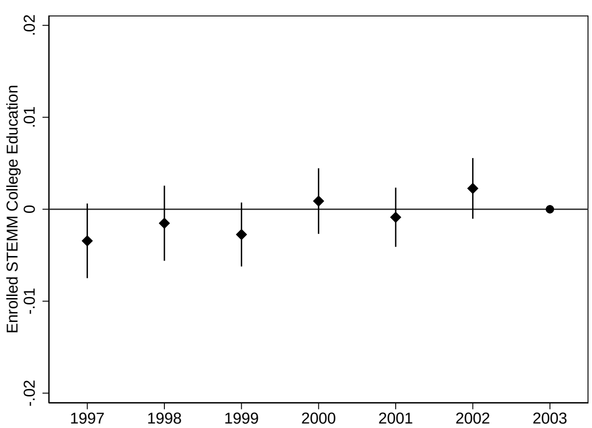
(c) HS Dropout



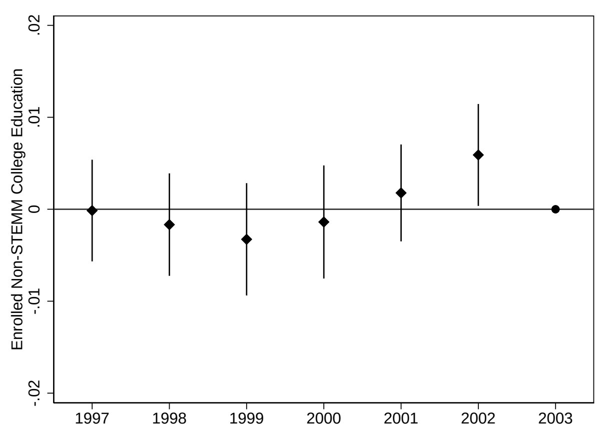
(d) Enrollment in College Education



(e) Enrollment in College Education, STEM



(f) Enrollment in College Education, Non-STEM

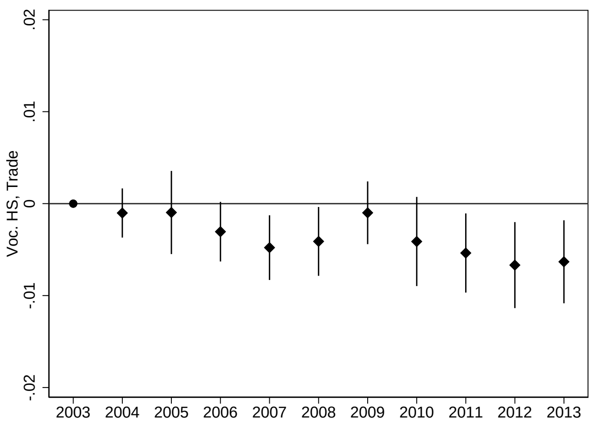


Notes: Figure plots estimates of β_{1c} from equation (3), fixing ΔZ_{mc} to the change in RSH from 2003–2013 and using cohorts born prior to the shock. Outcome variable is measured as the different in education relative to the initial cohort (1987 cohort aged 16 in 2003), using cohorts born prior to 1987 from 1982–1986. Year plotted on x-axis corresponds to the year a birth cohort faces the RTI shock at age 16. Coefficients are scaled by average change in the Bartik shock from 2003–2013. 95% confidence intervals plotted.

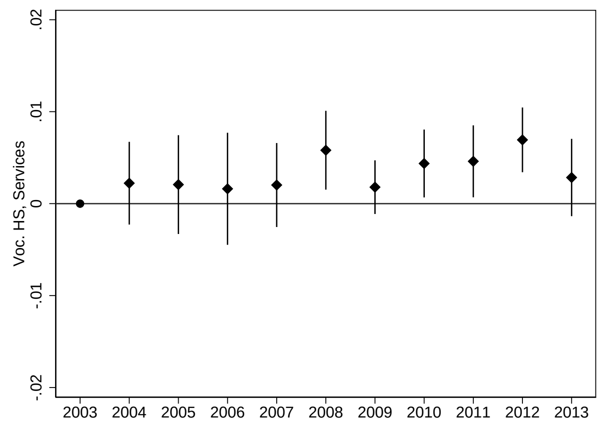
H.2 Including Services in RTI Measure

Figure H.2: The Effect of Declining Routine Task Intensity on Educational Investments, Including Services into Measure of RTI

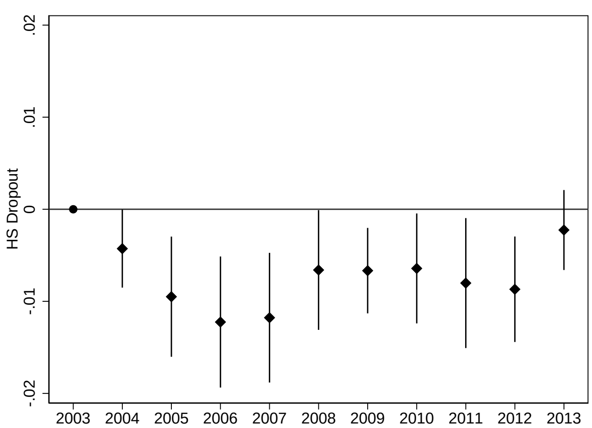
(a) Voc. HS, Trades



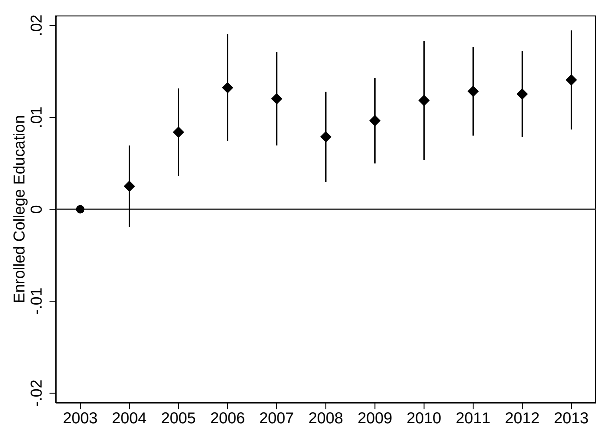
(b) Voc. HS, Services



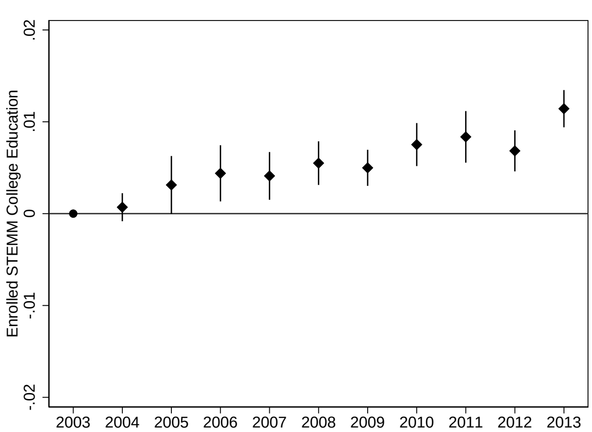
(c) HS Dropout



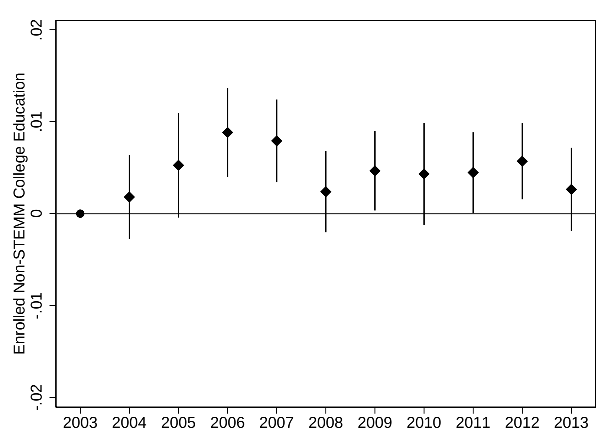
(d) Enrollment in College Education



(e) Enrollment in College Education, STEM



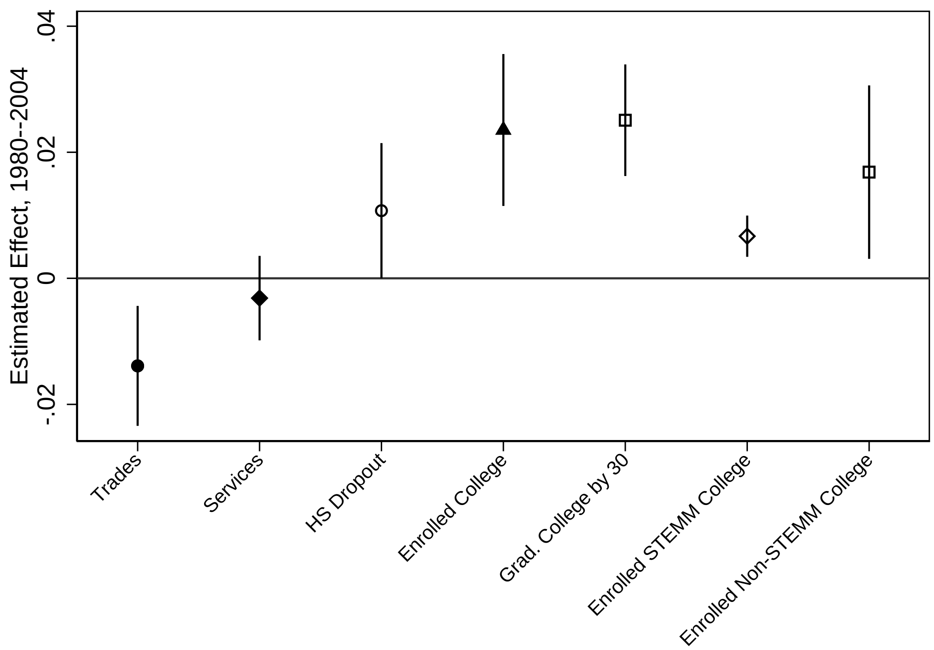
(f) Enrollment in College Education, Non-STEM



Notes: Figure plots estimates of β_{1c} from equation (3), changing measure of ΔRSH_{mc+16}. Year plotted on x-axis corresponds to the year a birth cohort faces the RTI shock at age 16. RTI measure including services defined as: $RTI_j = lnR_j - lnM_j - lnS_j$, where $R_j, M_j, and S_j$ correspond to routine, math, and services respectively. Coefficients are scaled by average change in the Bartik shock in each year. 95% confidence intervals plotted.

H.3 The Long Run Impact of Labor Demand Shocks on Educational Investments, 1980–2004

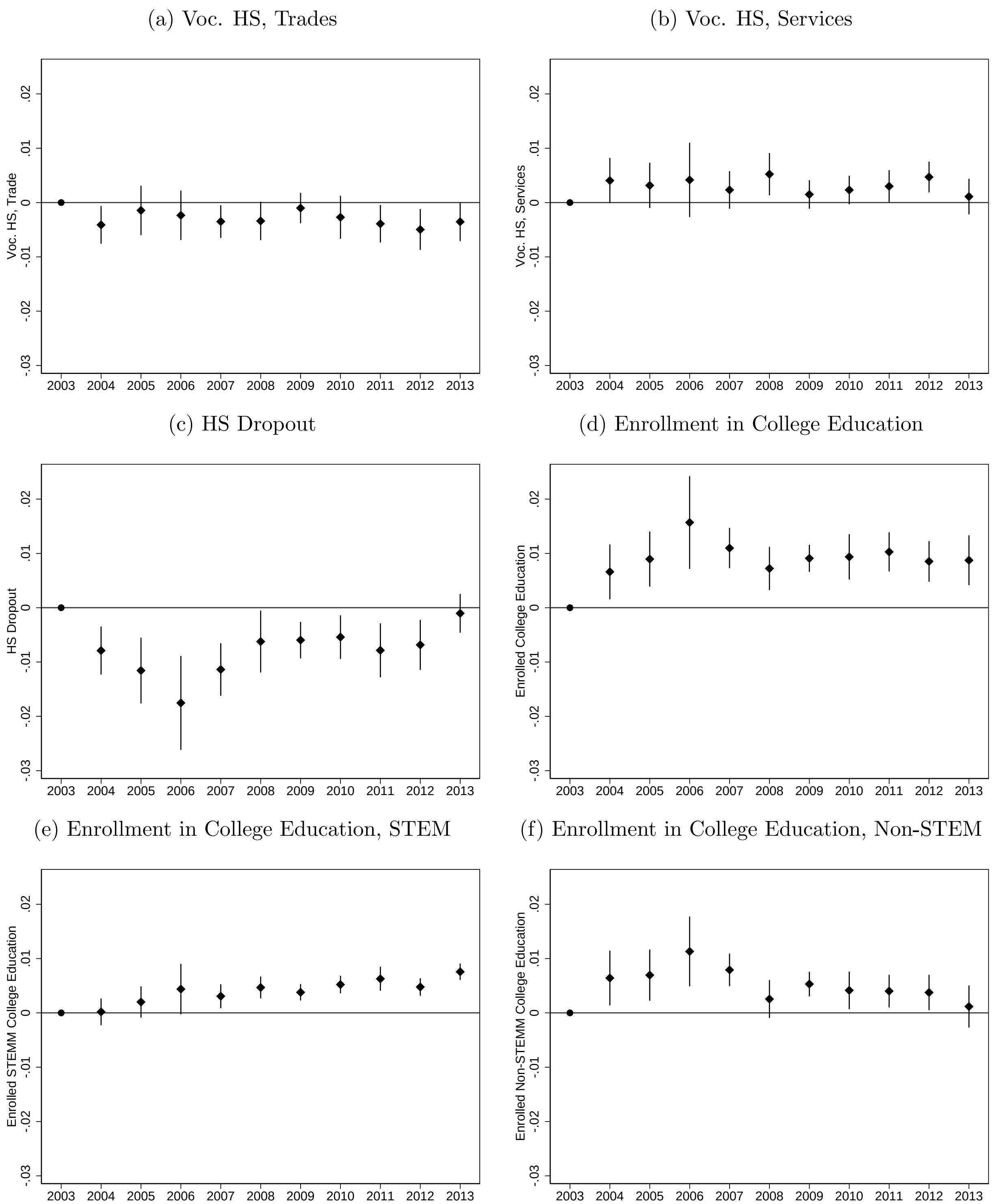
Figure H.3: The Long Run Impact of Labor Demand Shocks on Educational Investments, from 1980–2004



Notes: Figure plots estimates of β_{1c} from equation (3), changing base cohort from 1987 (age 16 in 2003) to 1964 cohort (age 16 in 1980). Plotted coefficients are the long-run difference from 1980–2004, comparing the educational investments of the 1964 birth cohort to the 1988 birth cohort. Coefficients are scaled by average change in the Bartik shock in each year. 95% confidence intervals plotted.

H.4 Using the Initial Area-level Share of Occupations in 1980

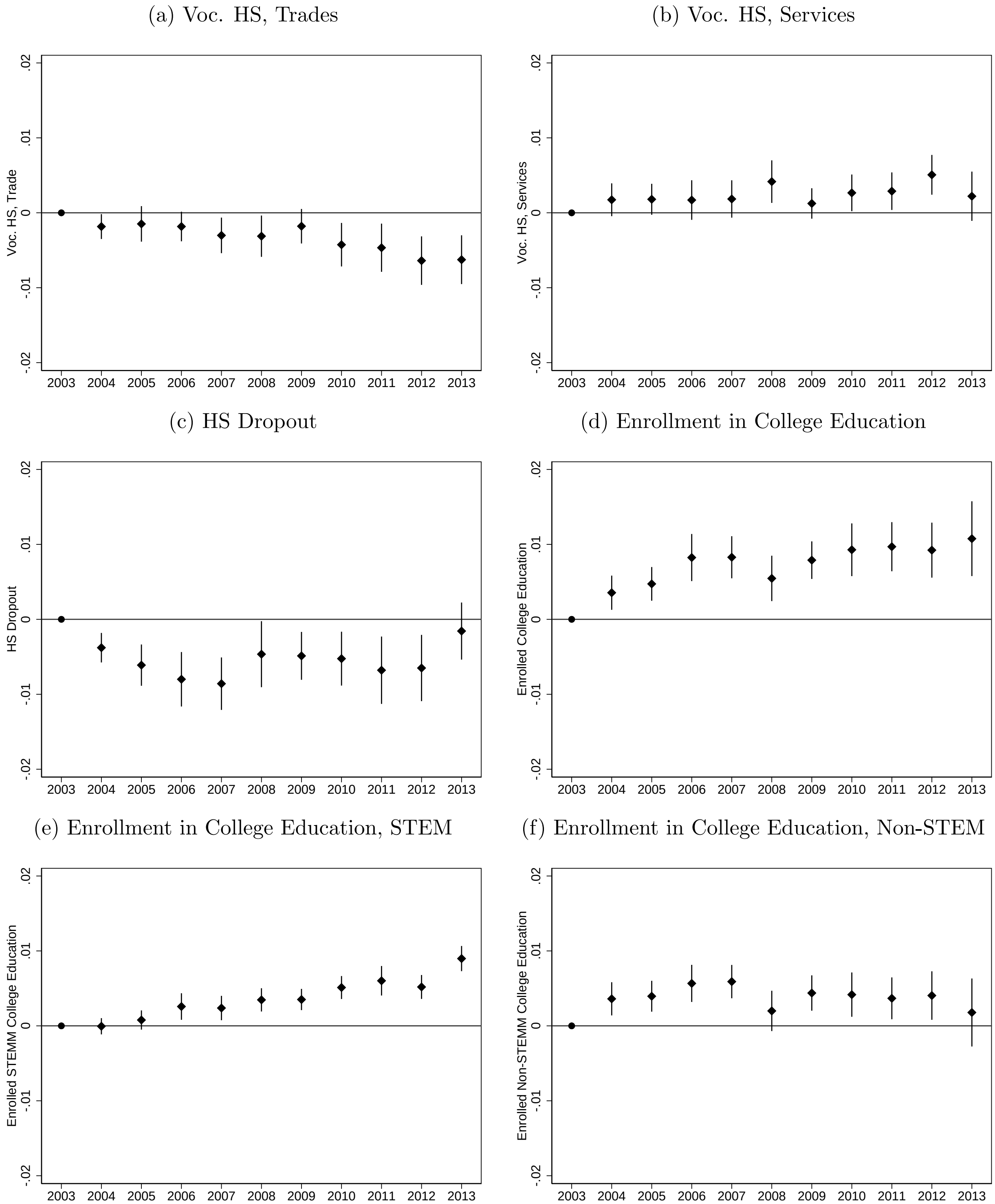
Figure H.4: The Effect of Declining Routine Task Intensity on Educational Investments, 1980 Area-level Occupational Share



Notes: Figure plots estimates of β_{1c} from equation (3), altering the measure of ΔRSH_{mc+16} by defining $\frac{L_{mj1980}}{L_{m1980}}$ from equation (1). Year plotted on x-axis corresponds to the year a birth cohort faces the RTI shock at age 16. RTI measure including services defined as: $RTI_j = lnR_j - lnM_j - lnS_j$, where $R_j, M_j, and S_j$ correspond to routine, math, and services respectively. Coefficients are scaled by average change in the Bartik shock in each year. 95% confidence intervals plotted.

H.5 Leave-One-Out Design

Figure H.5: The Effect of Declining Routine Task Intensity on Educational Investments, Leave-One-Out Bartik

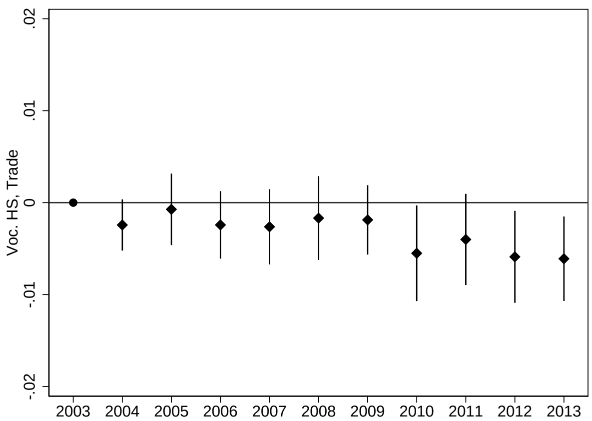


Notes: Figure plots estimates of β_{1c} from equation (3), changing definition of Bartik shock to calculate ΔRSH_{mc+16} excluding the CZ itself from $(lnL_{jt} - lnL_{jt^0})$ in equation (1). Year plotted on x-axis corresponds to the year a birth cohort faces the RTI shock at age 16. Coefficients are scaled by average change in the Bartik shock in each year. 95% confidence intervals plotted.

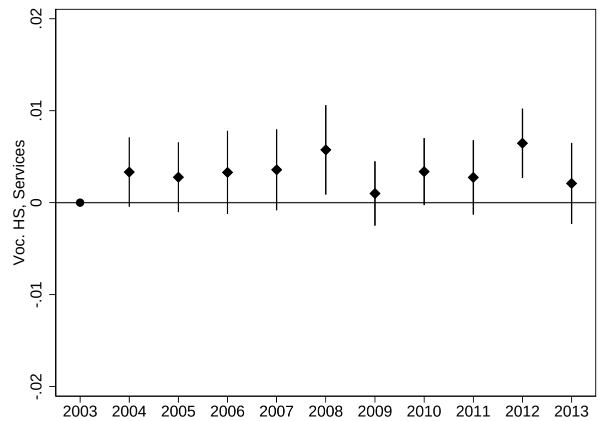
H.6 Controlling for Change in Immigration in Each Year

Figure H.6: The Effect of Declining Routine Task Intensity on Educational Investments, Controlling for Change in Immigration

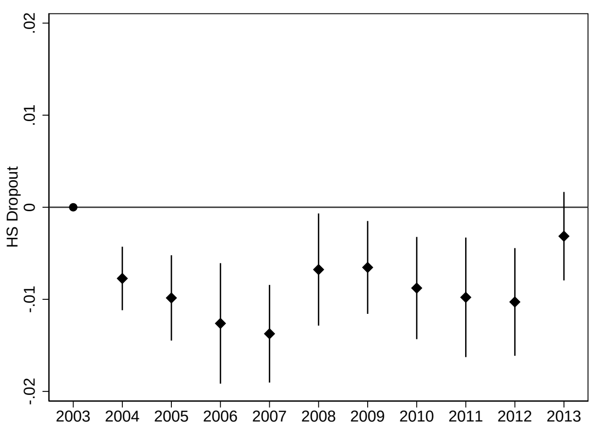
(a) Voc. HS, Trades



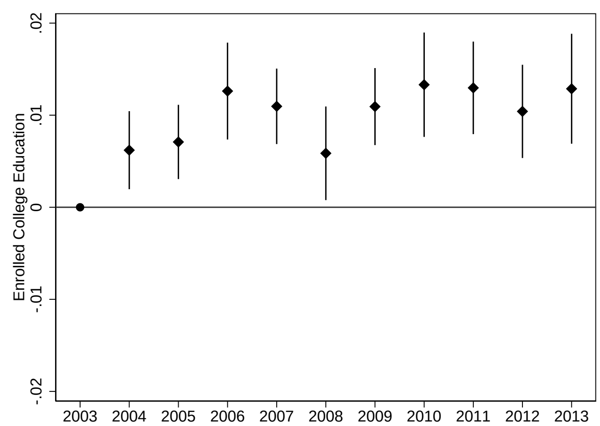
(b) Voc. HS, Services



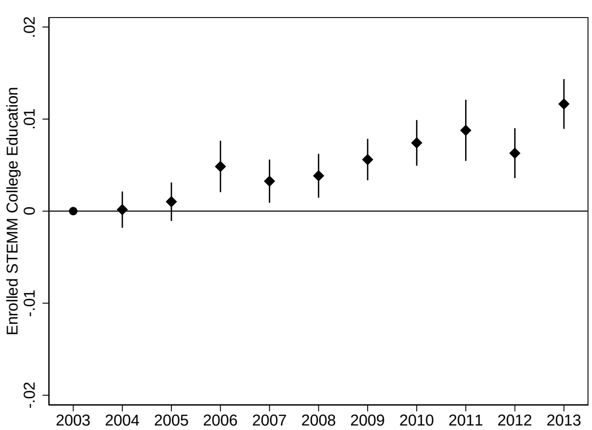
(c) HS Dropout



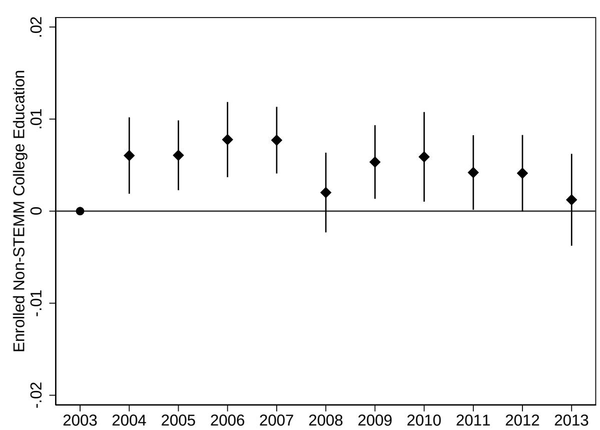
(d) Enrollment in College Education



(e) Enrollment in College Education, STEM



(f) Enrollment in College Education, Non-STEM

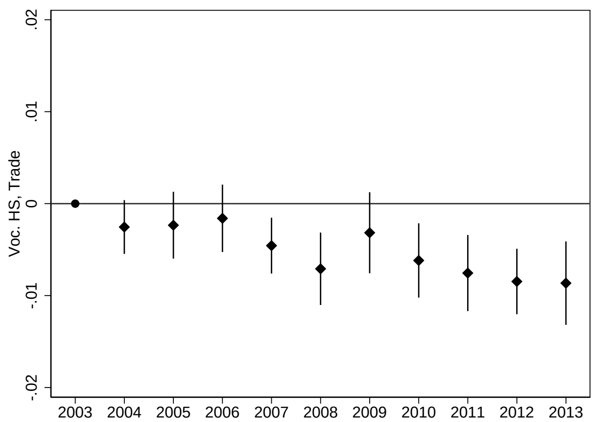


Notes: Figure plots estimates of β_{1c} from equation (3), including the change in share of Poles residing in each CZ to account for the expansion of the EU in 2004 where a large influx of Polish workers immigrated to Norway. Year plotted on x-axis corresponds to the year a birth cohort faces the RTI shock at age 16. Coefficients are scaled by average change in the Bartik shock in each year. 95% confidence intervals plotted.

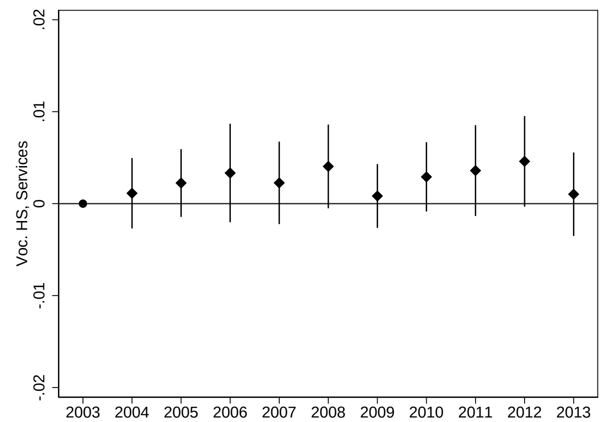
H.7 Using CZ of Birth

Figure H.7: The Effect of Declining Routine Task Intensity on Educational Investments, Using CZ of Birth

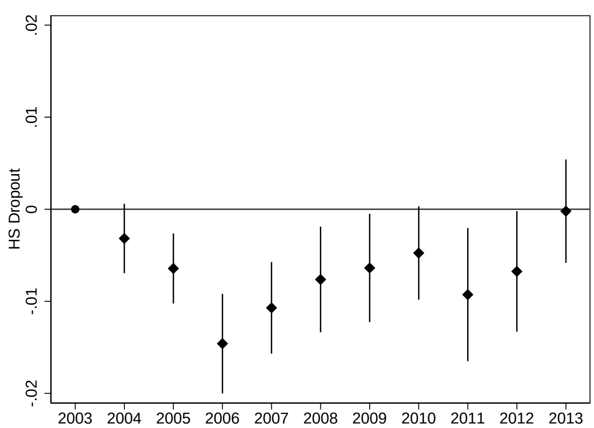
(a) Voc. HS, Trades



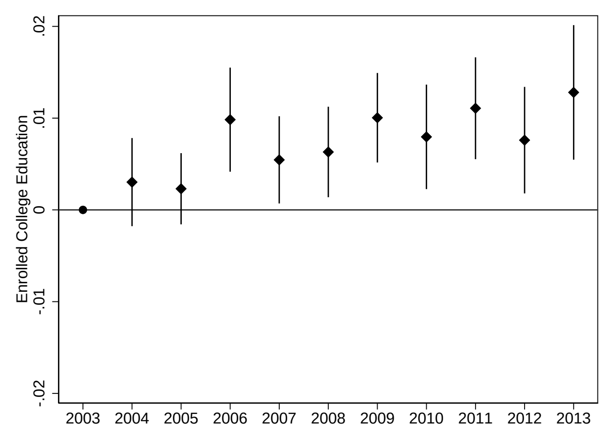
(b) Voc. HS, Services



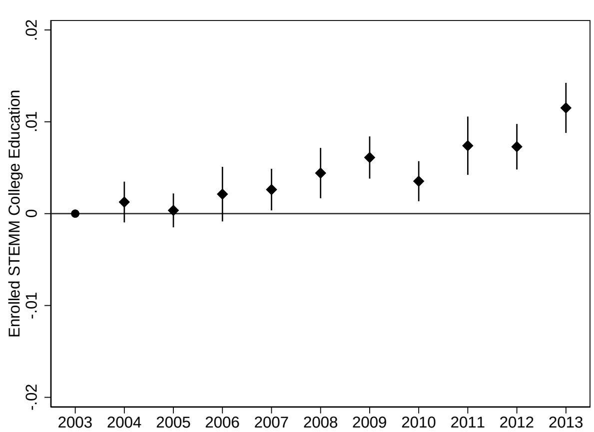
(c) HS Dropout



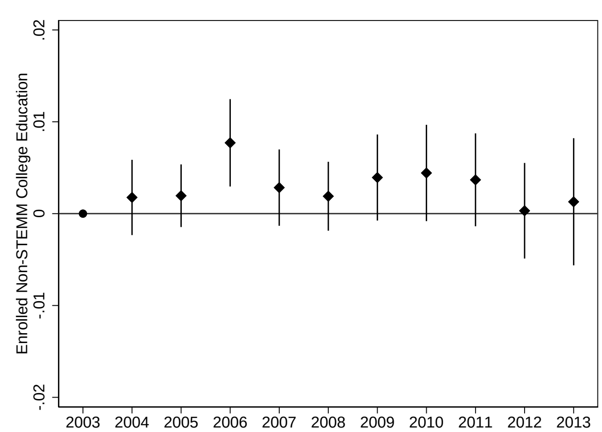
(d) Enrollment in College Education



(e) Enrollment in College Education, STEM



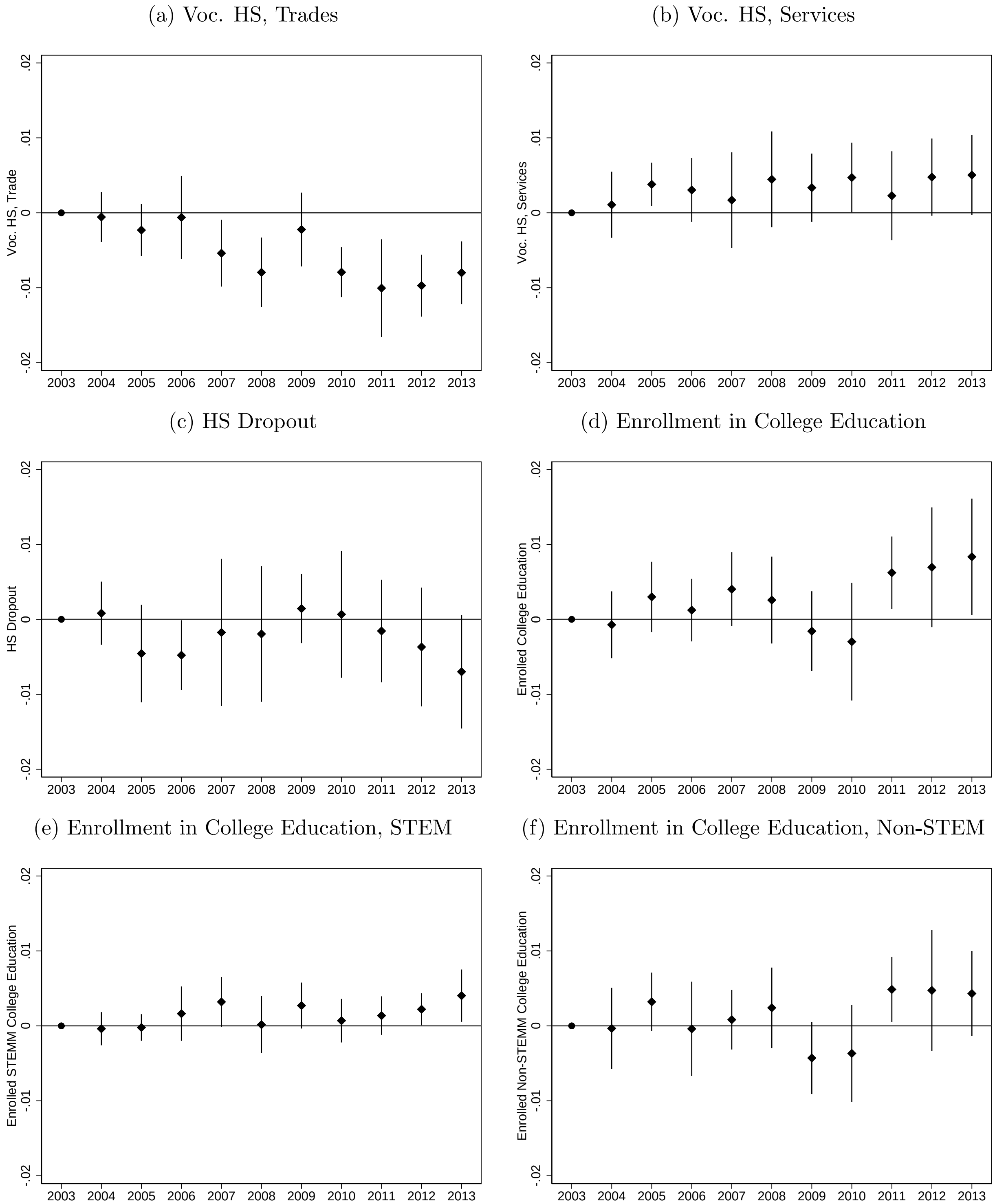
(f) Enrollment in College Education, Non-STEM



Notes: Figure plots estimates of β_{1c} from equation (3), changing the CZ from the CZ of residence at age 16 to the CZ of birth among those born in Norway for whom data on birthplace is available. Year plotted on x-axis corresponds to the year a birth cohort faces the RTI shock at age 16. Coefficients are scaled by average change in the Bartik shock in each year. 95% confidence intervals plotted.

H.8 Excluding Large Urban Areas

Figure H.8: The Effect of Declining Routine Task Intensity on Educational Investments, Excluding Large Urban Areas



Notes: Figure plots estimates of β_{1c} from equation (3), changing estimation sample to exclude large urban areas. Year plotted on x-axis corresponds to the year a birth cohort faces the RTI shock at age 16. Coefficients are scaled by average change in the Bartik shock in each year. 95% confidence intervals plotted. Sample excludes the CZs of Oslo, Bergen, Stavanger, Trondheim, Kristiansand, and Tromsø.

I The Effect of Local Demand Changes on Education Investments by Maternal Education, 2003–2013

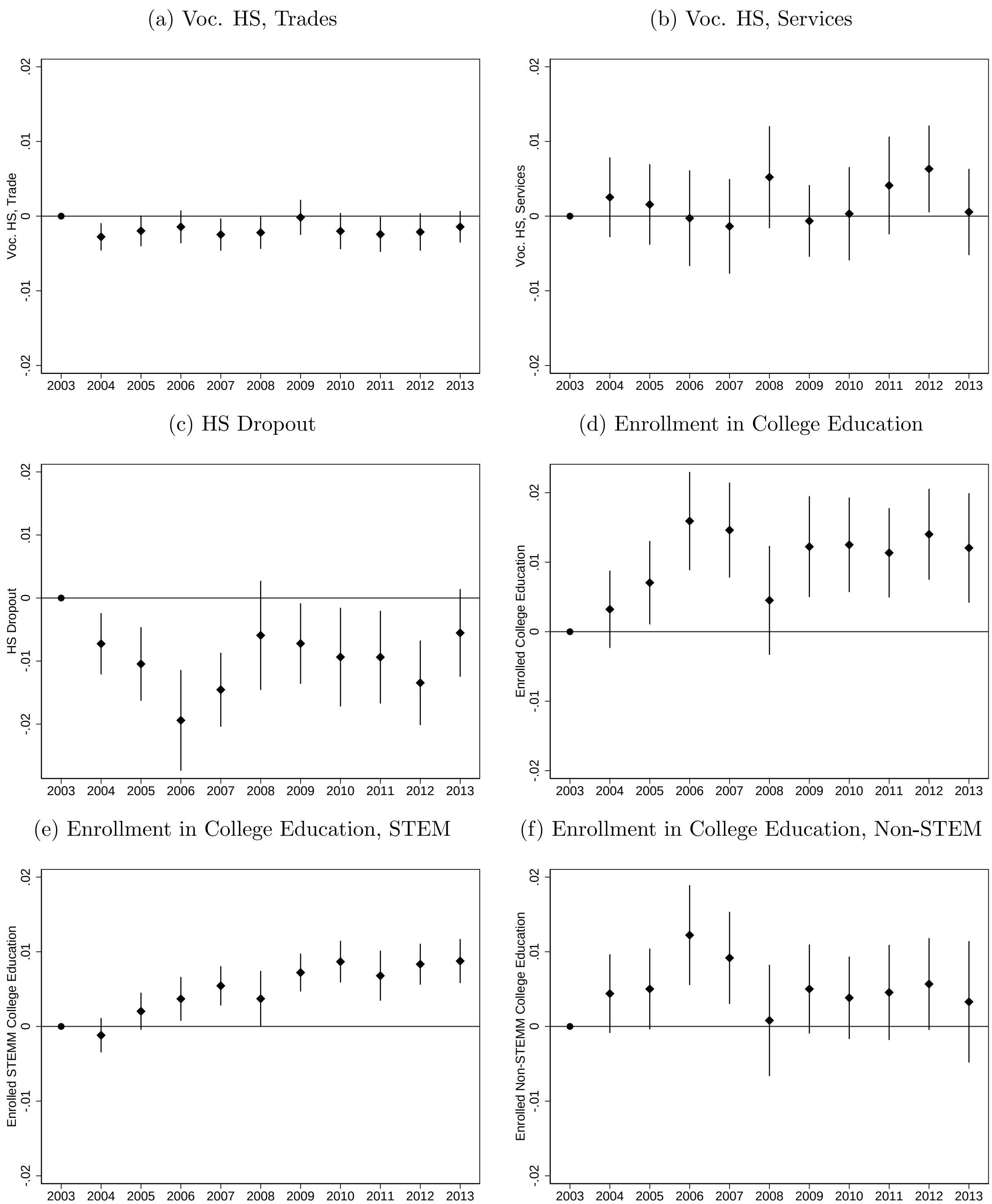
Table I.1: The Effect of Local Demand Changes on Education Investments by Ability & Parental Education, 2003–2013

	GPA		Mother's Education		GPA		Mother's Education	
	Top (1)	Bottom (2)	High (3)	Low (4)	Top (5)	Bottom (6)	High (7)	Low (8)
	Panel A: Voc HS, trades				*Panel B: Voc HS, services*			
point estimate, 2003-2013	-0.000	-0.015***	-0.010***	-0.005**	-0.003	0.008***	-0.000	0.003
	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)
% of mean	[-0.3]	[-9.8]	[-8.5]	[-3.4]	[-3.1]	[8.6]	[-0.1]	[2.1]
	Panel C: HS dropout				*Panel D: enrollment in college*			
point estimate, 2003-2013	0.001	-0.003	0.006**	-0.008***	0.002	0.011***	0.009**	0.016***
	(0.002)	(0.005)	(0.003)	(0.002)	(0.004)	(0.003)	(0.004)	(0.003)
% of mean	[1.0]	[-0.4]	[3.0]	[-2.0]	[0.2]	[19.6]	[1.8]	[5.6]
	Panel E: enrollment in college, STEMM				*Panel F: enrollment in college, Non-STEMM*			
point estimate, 2003-2013	0.013***	0.004**	0.018***	0.006***	-0.012***	0.007***	-0.008**	0.010***
	(0.003)	(0.002)	(0.002)	(0.001)	(0.004)	(0.003)	(0.004)	(0.003)
% of mean	[7.1]	[15.3]	[14.2]	[10.8]	[-2.0]	[23.5]	[-2.1]	[4.3]

Standard errors reported in parentheses clustered at the commuting zone (CZ) level. ***, **, and * correspond to significance at the 1%, 5%, and 10% levels respectively. *Notes:* Table shows estimates of β_{1c} from equation (3), scaled by average change in the Bartik shock. Point estimate calculated as a percent of the mean of the initial cohort reported in brackets. Estimation period is 10 year difference from 2003–2013. High ability in columns (1) & (5) defined as student in the top 25% of middle school GPA distribution. Low ability in columns (2) & (6) defined as student in the bottom 25% of middle school GPA distribution. High-educated in columns (3) & (7) defined as student whose mother is a college graduate. Low-educated in columns (4) & (8) defined as student whose mother is non-college educated. Sample of 160 CZs. Estimating equation: $\Delta Y_{gmc} = \beta_{0gc} + \beta_{1c}\Delta RSH_{mc} + \beta_{2c}X_m + \varepsilon_{gmc}$, where g corresponds to each of the GPA/mother's education groups.

I.1 Separately Analyzing Women and Men

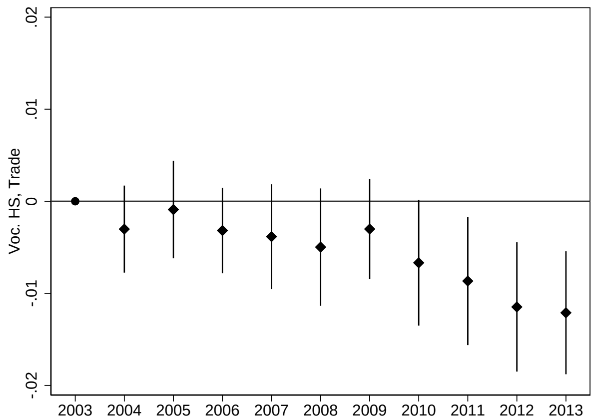
Figure I.1: The Effect of Declining Routine Task Intensity on Educational Investments, Female Sample



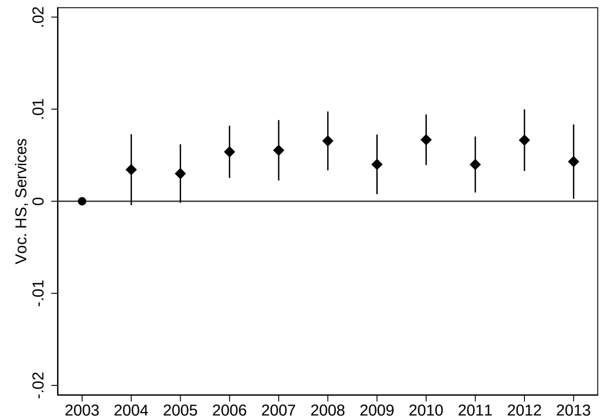
Notes: Figure plots estimates of β_{1c} from equation (3), for the sample of female students. Year plotted on x-axis corresponds to the year a birth cohort faces the RTI shock at age 16. Coefficients are scaled by average change in the Bartik shock in each year. 95% confidence intervals plotted.

Figure I.2: The Effect of Declining Routine Task Intensity on Educational Investments, Male Sample

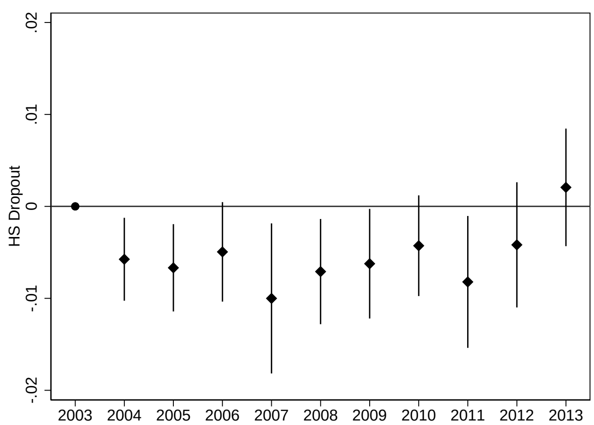
(a) Voc. HS, Trades



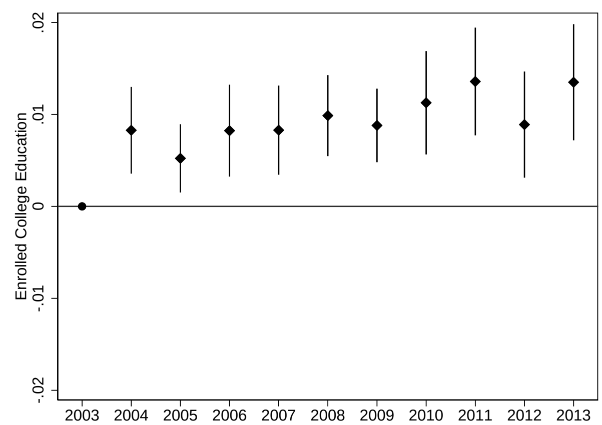
(b) Voc. HS, Services



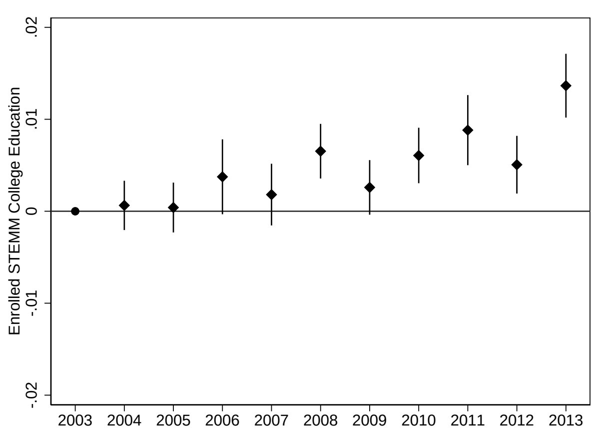
(c) HS Dropout



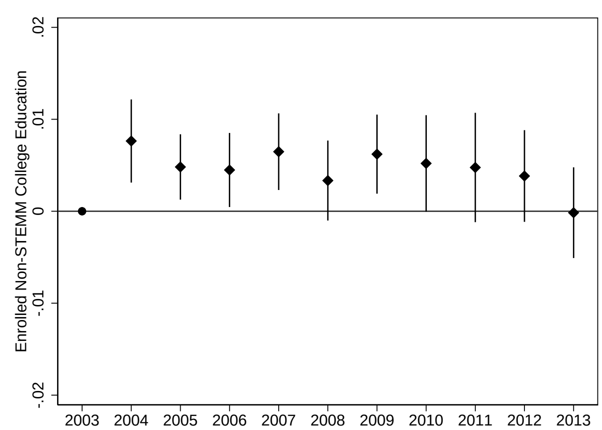
(d) Enrollment in College Education



(e) Enrollment in College Education, STEM



(f) Enrollment in College Education, Non-STEM



Notes: Figure plots estimates of β_{1c} from equation (3), for the sample of male students. Year plotted on x-axis corresponds to the year a birth cohort faces the RTI shock at age 16. Coefficients are scaled by average change in the Bartik shock in each year. 95% confidence intervals plotted.

J The Relationship Between Father's Education & Child GPA

Figure J.1: Distribution of Middle School GPA by Father's Education Level

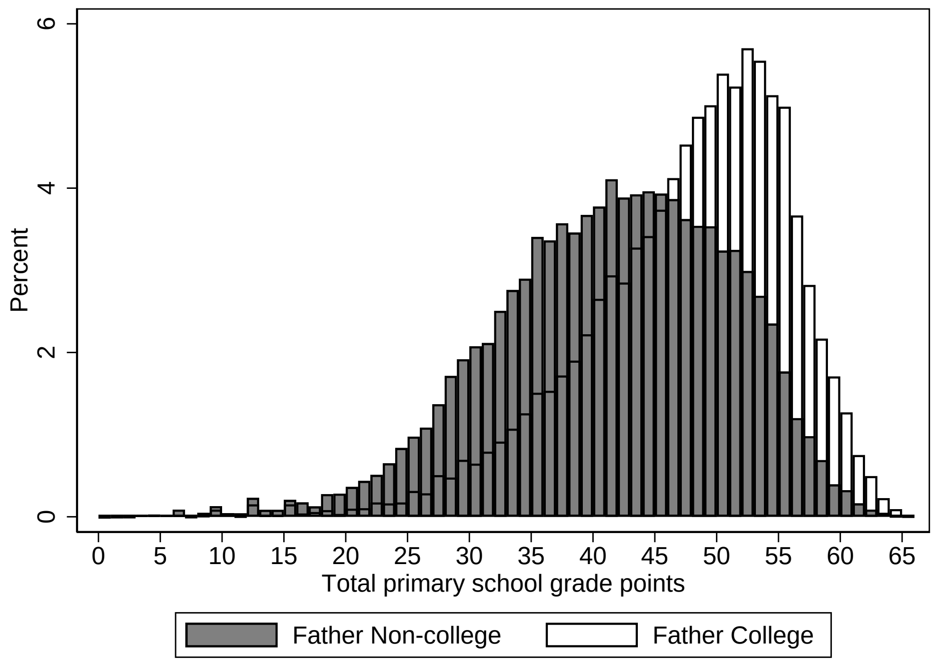


Figure plots the distribution of middle school GPA for birth cohort 2003 separately by those with a high and low educated father. Each bar corresponds to a 1 unit difference in GPA, measured from 0–66. High/low ability father defined as whether or not father graduated from college.

K Differences in the Response to Local Demand Shocks by Ability, Conditioning on high/low-educated Families

Table K.1: Initial Field of Study Choices by Ability and SES, 2003

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
					Low Educated		High Educated	
	Low GPA	High GPA	Low Educated	High Educated	Low GPA	High GPA	Low GPA	High GPA
trades	14.7%	4.0%	14.1%	7.1%	14.3%	6.1%	13.7%	2.1%
services	9.0%	8.4%	13.3%	8.9%	9.1%	10.9%	8.8%	6.1%
dropout	70.8%	5.3%	36.9%	18.7%	71.7%	5.8%	65.0%	4.9%
enrolled college	4.9%	78.1%	30.8%	59.6%	3.9%	72.6%	10.4%	83.0%
STEM	1.2%	21.6%	5.8%	16.8%	1.0%	16.0%	2.4%	26.6%
non-STEM	3.6%	56.5%	25.0%	42.7%	2.9%	56.6%	8.0%	56.3%
N	12716	13405	35464	17149	10797	6338	1919	7067

Notes: Table reports the distribution of fields of study choices by low/high-ability students (columns (1)–(2), low/high-educated students (columns (3)–(4), low/high-ability students among the low-educated families (columns (5)–(6), and low/high-ability students among the high-educated families (columns (7)–(8). Low/high ability defined as being in the bottom/top 25% of the cohort specific middle school GPA distribution respectively. Low/high-educated family defined as a father who is non-college/college educated respectively.

Table K.2: The Effect of Local Demand Changes on Education Investments by Low/High Educated Father and by Ability, 2003–2013

	Low Educated Father		High Educated Father	Low Educated Father		High Educated Father
	Low GPA	High GPA	High GPA	Low GPA	High GPA	High GPA
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: Voc HS, trades			*Panel B: Voc HS, services*		
point estimate, 2003-2013	-0.013***	0.000	0.002	0.007**	-0.000	-0.006
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
% of mean	[-8.2]	[0.2]	[4.5]	[7.7]	[-0.3]	[-10.0]
	Panel C: HS dropout			*Panel D: enrollment in college*		
point estimate, 2003-2013	-0.001	-0.000	0.000	0.010***	0.008	-0.004
	(0.006)	(0.003)	(0.004)	(0.002)	(0.006)	(0.007)
% of mean	[-0.01]	[-0.6]	[0.0]	[18.5]	[1.0]	[-0.5]
	Panel E: enrollment in college, STEM			*Panel F: enrollment in college, Non-STEM*		
point estimate, 2003-2013	0.005***	0.007*	0.025***	0.005**	0.001	-0.029***
	(0.001)	(0.004)	(0.005)	(0.002)	(0.007)	(0.007)
% of mean	[18.7]	[4.5]	[10.3]	[18.3]	[0.2]	[-5.0]

Standard errors reported in parentheses clustered at the commuting zone (CZ) level. ***, **, and * correspond to significance at the 1%, 5%, and 10% levels respectively. *Notes:* Table shows estimates of β_{1c} from equation (3), scaled by average change in the Bartik shock. Point estimate calculated as a percent of the mean of the initial cohort reported in brackets. Estimation period is 10 year difference from 2003–2013. High ability in columns (2)–(3) & (5)–(6) defined as student in the top 25% of middle school GPA distribution. Low ability in columns (1) & (4) defined as student in the bottom 25% of middle school GPA distribution. High-educated in columns (3) & (6) defined as student whose father is college educated. Low-educated in columns (1)–(2) & (4)–(5) defined as student whose father is a non-college graduate. Sample of 160 CZs. Estimating equation: $\Delta Y_{gmc} = \beta_{0gc} + \beta_{1c}\Delta RSH_{mc} + \beta_{2c}X_m + \varepsilon_{gmc}$, where g corresponds to each of the combined groups of father's education & GPA.

References

Autor, D. H. (2019, May). Work of the past, work of the future. *AEA Papers and Proceedings 109*, 1–32.

Bennett, P., R. Blundell, and K. G. Salvanes (2020, August). A second chance? Labor market returns to adult education using school reforms. IFS Working Papers W20/28, Institute for Fiscal Studies.

Bratsberg, B. and O. Raaum (2012). Immigration and wages: Evidence from construction. *The Economic Journal 122*(565), 1177–1205.

Deming, D. J. (2017). The growing importance of social skills in the labor market. *The Quarterly Journal of Economics 132*(4), 1593–1640.