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College-High School Wage and Human Capital Price Differentials, and the Role of Mobility for Local Wages in the U.S.

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A thesis submitted in partial fulfillment of the requirements for the Doctor of Philosophy degree in Economics

COLLEGE-HIGH SCHOOL WAGE AND HUMAN CAPITAL PRICE DIFFERENTIALS, AND THE ROLE OF MOBILITY FOR LOCAL WAGES IN THE U.S.

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Abstract

This thesis contains three studies on national and local college wage premia, skill premia, and implications of geographic mobility for local wages. The second chapter investigates the reasons for problems with the standard supply-demand model of skill premium. This chapter shows that the problems of canonical model can be explained by mismeasurement of skills and skill prices. The standard approach assumes changes in wages are driven by changes in skill prices alone, and not by skill levels. We re-estimate the canonical model allowing for changes in skill levels over time. The results show that the demand changes have a much smaller role, and that the elasticity of substitution between college and high school labour is higher compared to the standard approach. The model also yields a much better out-of-sample prediction for the college wage premium.

The third chapter examines whether implications of the canonical model continue to hold at the Census regional level using the more general approach in the second chapter. Relaxing the assumption of constant skill levels, this chapter shows that the movements in relative wages mask important trend differences in relative skill prices across regions. The results show that while the standard approach suggests very different relative demand patterns across regions, the alternative approach shows much closer patterns. In addition, elasticities of substitution between college and high school labour are more similar across regions compared to the standard approach. Therefore, differences in changes in relative skill prices across regions are mainly driven by differences in relative skill supply patterns.

The fourth chapter presents recent evidence on the comparison of responsiveness of college and high school graduate wages to local demand shocks in the U.S. This chapter shows that there are significant wage effects of local demand shocks in the 1980s, which decline over time for both groups. Moreover, wage effects are deeper for high school graduates during the 1980s and 1990s, but they converge during the 2000s. This is also accompanied by converging annual inter-state mobility rates between the two education groups compared to the 1980s and 1990s, which confirms the importance of labour reallocation across markets.

Keywords: Human capital, college wage premium, skill premium, skill-biased technological change, elasticity of substitution, local labour markets, mobility

Co-Authorship Statement

This thesis contains material co-authored with Audra Bowlus, Lance Lochner and Chris Robinson. All the authors are equally responsible for the work which appears in Chapter 2 of this thesis.

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Eda Bozkurt

London, Canada
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To my parents.

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Chapter 1

Introduction

The increase in returns to college education during the 1980s triggered an extensive literature on understanding the mechanisms behind these changes in the wage structure. The two main channels that are shown to shape the evolution of the wage gap between college and high school graduate labour are changes in relative demand and supply for college graduates labour. Demand explanations suggest that relative demand for college vs high school graduate labour increased as the economy became more technologically advanced (e.g. Katz and Murphy (1992), Katz and Autor (1999), Card and Lemieux (2001)), whereas supply explanations include increased immigration of low-skilled labour in the U.S. (Topel (1997)) and limited geographic mobility of more-experienced and less-educated groups (Bound and Holzer (2000), Topel (1986)). The national market is made up of distinct local markets with their own labour market dynamics, which motivated exploiting local variations in relative demand and supply for college labour to understand changes in the wage structure (Topel (1986), Bound and Holzer (2000), Ciccone and Peri (2005), Lindley and Machin (2013)). My dissertation contributes to this literature by examining changes in college-high school wage gap and human capital price differentials both at the national and local level, and presenting recent evidence on the implications of geographic mobility for wages of college and high school graduate labour.

The second chapter, co-authored with Audra Bowlus, Lance Lochner and Chris Robinson, investigates the reasons for problems with the standard supply-demand model of college-high school relative skill prices as noted in Acemoglu and Autor (2011). The *canonical* supply-demand model of skill prices produces poor out-of-sample predictions and unstable estimates for relative demand changes (skill-biased technological change (SBTC) induced) and elasticities of substitution between college and high school labour when estimated over a long period of time, and yields counter-intuitive estimates for the relative demand growth for the 1990s. The standard approach to estimating this model is to use relative wages adjusted for changes in the composition of high vs low skill workers due to shifts in education-gender-experience composition of the labour force to proxy for relative skill prices and composition adjusted relative total hours to proxy for relative supply. This imposes a very strong assumption of constant skill levels within these groups over time.

This chapter shows that the troubling empirical findings coming from typical estimates of the canonical model can be explained by mismeasurement of skills and skill prices. We re-estimate the canonical model using the relative skill price and quantities in Bowlus and Robinson (2012), who allow for changes in skill levels over time within observable groups, unlike the standard approach. We find a smaller role for SBTC for changes in college wage premium and a higher elasticity of substitution between college and high school labour. Furthermore, the model yields a much better out-of-sample prediction for college wage premium over the 1988-2008 period when estimated using these relative skill price and supply series compared to the standard approach.

The U.S. labour market is composed of distinct local labour markets, which have different dynamics within them. The third chapter examines whether implications of the canonical model continue to hold at the Census regional level using the more general approach to estimating college-high school relative skill prices and supplies as in the second chapter.

In the canonical model, differences in relative skill price paths across regions are determined by differences in relative college-high school skill supply, relative skill demand, and elasticities of substitution between college-high school labour across regions. Relaxing the assumption of constant skill levels, I show that relative skill prices exhibit a decreasing pattern between the 1960s and 1980s in the Midwest, and between the 1960s and 1990s in the Northeast, while the West and South saw increasing relative skill prices over these periods. On the other hand, movements in college wage premia are similar across regions, and during the 1960s and 1980s college wage premia (proxies for relative skill prices used by the standard approach) increased in all regions. Therefore, movements in relative wages mask important trend differences in relative skill prices across regions. In other words, these differences in trends in relative skill prices and college wage premium imply that there are in fact significant changes at the regional level in relative skill levels (quality) of college and high school labour over these periods.

The more general approach to implementing the canonical model yields very different results in terms of reasons of differences in regional trends in relative skill prices compared to the standard approach. While the standard approach suggests very different relative demand patterns across regions, the alternative approach shows much closer patterns. In addition, estimates show that elasticities of substitution between college and high school labour are more similar across regions compared to the standard approach. Therefore, differences in changes in relative skill prices are mainly driven by differences in relative skill supply patterns.

One of the channels that can affect the path of college wage premium is how college and high school labour respond to local demand shocks. The fourth chapter presents recent evidence on the comparison of responsiveness of college and high school graduate wages to local demand shocks in the U.S. When a *skill-neutral* negative demand shock hits a local market, a decrease in wages will trigger out-migration from that market. Mobility across markets is not perfect, and some groups are less mobile than others (e.g. high school graduates are less mobile than college graduates (Greenwood (1975), Wozniak (2010))) This means that there will be excess supply of the less mobile groups in the market following the out-migration of other groups, which will deepen the wage effects of *skill-neutral* demand shocks for less mobile workers. Topel (1986) and Bound and Holzer (2000) find supporting evidence for this for the late 1970s and 1980s, respectively.

This chapter investigates whether there are significant short-term effects of local demand shocks on wages during the 1980s, 1990s and 2000s, and whether differences in wage effects between different education groups persist over time. The main focus is on differences between high school and college graduates. Defining local labour markets by states, I find that there are significant wage effects of local demand shocks in the 1980s, but they decline over time for both high school and college graduates. Moreover, wage effects are deeper for high school graduates during the 1980s and 1990s, but differences in wage effects disappear during the 2000s. Furthermore, convergence in wage effects is also accompanied by converging annual inter-state mobility rates between the two education groups compared to the 1980s and 1990s. This confirms the importance of labour reallocation across markets following local demand shocks for wage changes.

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Chapter 2

Wages and Employment: The Canonical Model Revisited

2.1 Introduction

A basic supply-demand framework has formed the basis of a large body of research on the determinants of wages and employment in the post war US economy. The specific simple form of this framework used most notably in Katz and Murphy (1992) and Card and Lemieux (2001), was recently termed the "canonical model" in Acemoglu and Autor (2011). The canonical model is a model of the demand and supply of two types of skills, low or "high school type" skill, and high or "college type" skill in which relative prices (and quantities) of the skills are determined. The primary motivation for this literature is to understand the role that supply and demand factors, especially technological changes, have had on the path of the relative skill price or "skill premium". In particular, to explain how unskilled worker wages have been depressed relative to skilled worker wages even while the relative supply of skilled workers has increased. The key estimated parameters of this model that provide the explanation are the relative skill demand shift parameters that represent skill biased technological change (SBTC), and the elasticity of substitution between skilled and unskilled workers.

The implementation of the model in the literature uses composition adjusted relative wages as a proxy for relative prices, and composition adjusted hours as a proxy for relative quantities. As Acemoglu and Autor (2011) note, this simple model, with exogenous supplies determined by demographic factors, and a linear trend representing the demand effects of SBTC, fits the evolution of the skill premium over the 1963-1987 period studied by Katz and Murphy (1992) remarkably well. The estimates show a major role for SBTC and a relatively low (1.6 - 1.8) elasticity of substitution between the two skill levels, σ.[1] However, major problems have arisen in identifying SBTC induced demand changes and the magnitude of σ, when the model is estimated over a longer period. As noted in Acemoglu and Autor (2011) and Autor, Katz and Kearney (2008), the Katz and Murphy (1992) model exhibits poor out of sample predictions and instability in the estimates of the elasticity of substitution and SBTC. Moreover, if a more flexible time trend is used to improve the out of sample predictions and stabilize the estimates of the elasticity of substitution, the implied time path of SBTC appears inconsistent with direct evidence, for example, from computer use.

Acemoglu and Autor (2011) also notes that the canonical model could not explain wage polarization, which is simultaneous growth of high and low wages in the wage distribution compared to wages in the middle of the distribution. They address this polarization with an enriched version of the canonical model which is a task-based model of wages and employment, where there is ”one-to-one mapping between skills and tasks”.[2] This chapter focuses only on the increase in college-high school wage premium.

[1] The literature has shown evidence of a major role for SBTC, either directly as linear trend changes in production function parameters as in Katz and Murphy (1992) type regressions, or indirectly where the trend may be a proxy for the capital skill complementarity effect. (See, for example, Krusell *et al.* (2000).)

[2] Acemoglu and Autor (2011) page 46.

A further problem with the basic aggregate canonical model first identified by Card and Lemieux (2001) is that it cannot explain differences in the path of the skill premium over time for different age groups. In particular, Card and Lemieux (2001) note the rapid rise in the skill premium from 1975-1995 was largely confined to younger workers. Card and Lemieux (2001) go someway to solving the problem by disaggregating the standard canonical model and allowing for imperfect substitutability across age groups. A comparison of the US, UK and Canada also produces problematic results for the canonical model. The estimates of SBTC and the elasticity of substitution for the US and UK reported in Card and Lemieux (2001)are quite similar, but not for Canada. In the model of Card and Lemieux (2001) the elasticity of substitution and SBTC are estimated simultaneously and Card and Lemieux (2001) argue that results for Canada may be unreliable due to multicollinearity in the Canadian data between the assumed time trend for the SBTC and the trend in the relative supply ratio. However, even assuming an elasticity of substitution for Canada of the same value as the approximately equal estimates for the US and the UK and then backing out the implied SBTC, the implied SBTC rates are much lower for Canada. This is surprising given that the Canadian and US economies are usually considered at least as similar, if not more so, as the UK and US economies.

An important goal of this chapter is to show that many of the problems with the canonical model result from implementing a demand-supply model for explaining relative skill prices using "composition adjusted" relative wages as the proxy for relative skill prices over a period in which up to two thirds of the change in "composition adjusted" relative wages is not in fact due to relative price changes. This leads to mis-leading results for both the role of SBTC and magnitude of σ, which are interconnected in the canonical model, when the model is implemented with composition adjusted wages and relative skill supplies. The composition adjustment approach goes someway to adjusting simple average wages or simple total hours for each skill type for the substantial changes that have occurred in the composition of the labor force in terms of the relative sizes of the age-sex-education cells for each skill type. However, it ignores major cohort effects that result in within age-sex-education cells for each skill type.[3] Since σ plays a significant role in the broader literature on human capital, the consequences of any mis-estimation of the parameters in the canonical model through the use of conventional composition adjusted price and quantity measures are far reaching.

Carneiro and Lee (2011) and Bowlus and Robinson (2012), following Heckman, Lochner and Taber (1998), draw attention to the distinction between relative wages and relative prices. The results in Bowlus and Robinson (2012) (hereafter BR) show that over the 1963-2008 period, to which the canonical model has been applied, there is a large difference in the behavior of composition adjusted relative wages and relative skill prices.[4] For example, a decomposition of the large increase in relative wages of young college workers compared to high school graduates in the 1975-2000 period, documented in Card and Lemieux (2001), shows that this was largely due to an increase in the amount of (skilled) human capital of the typical college graduate relative to the amount of (unskilled) human capital of the typical high school graduate over this period, with a relative price increase accounting for only one third of the increase in relative wages.

This chapter revisits the canonical model, but argues that due to cohort effects composition adjusted relative wages are not a good proxy for relative skill prices, and consequently composition adjusted supplies are a poor proxy for relative skill supplies. Instead of composition adjusted measures this chapter uses the skill price and quantity series derived in BR. Using BR relative prices in place of composition adjusted relative wages, the canon-

[3]See Carneiro and Lee (2011) and Bowlus and Robinson (2012).

[4]BR estimate price series using a “flat-spot” method, pioneered in Heckman, Lochner and Taber (1998), and using these series they estimate human capital profiles that vary across cohorts due to selection in education choice and technological change in human capital production. Carneiro and Lee (2011) using a different methodology focus on directly estimating selection effects and show the same pattern of variation in ‘quality’ of different birth cohorts of college graduates due to selection effects linked directly to enrolment rates.

ical model parameters are estimated and used to explain the path of relative prices. BR estimated price series for four skill types. A marked feature of the series is that they are highly correlated over a long period, suggesting a high elasticity of substitution, relative to the estimates in the literature. Estimates of the canonical model with the BR prices and quantities for the two skill types used in the canonical literature in fact show a much smaller role for SBTC and a much high elasticity of substitution than occurs when the standard composition adjusted measures are used. Moreover, in contrast to the standard implementation, there no significant out of sample prediction problem when parameters estimated on the Katz and Murphy (1992) period are used to predict over the 1988-2008 period.

Since (composition adjusted) relative wages, or the conventional skill premium remains a measure of great interest, an augmented version of the canonical model with BR quantities is developed to explain the path of relative wages in terms of a part due to relative price changes and a part due to relative changes the amount of (skilled) human capital of the typical college graduate relative to the amount of (unskilled) human capital of the typical high school graduate. SBTC is relevant for the first, but not the second. A decomposition shows that the relative price changes, and hence the role of SBTC on the path of relative wages, are much less important than estimated in the previous literature. As a byproduct, the clear cohort effects on the amount of (skilled) human capital of the typical college graduate documented in BR have an age pattern that largely obviates the need for extending the basic canonical model to allow for imperfect substitution by age within type in order to reconcile the model with the age patterns for relative wages in the data. In particular, given the cohort effects, the observed age pattern in relative wages is consistent with no age pattern in relative prices. In addition, Bowlus, Liu and Robinson (2012), in extending BR to Canada, shows a different relative price and quantity paths for Canada and the US which helps reconcile the problems the canonical model has in dealing with Canada.

The structure of the chapter is as follows. Section 2.2 summarizes the canonical model using the notation of Acemoglu and Autor (2011) and introduces the distinction between relative prices and composition adjusted relative wages in an augmented form of the basic model. In the augmented model cohort effects on the amount of (skilled) human capital of the typical college graduate relative to the amount of (unskilled) human capital of the typical high school graduate play a role that is identical to that of SBTC. Section 2.3 contrasts the implementation of the canonical model using skill prices and quantities of the type derived in BR with standard composition adjusted wages and quantities of Acemoglu and Autor (2011). It shows that when prices and quantities derived taking into account cohort effects are used, the simple canonical model with a linear trend estimated on the Katz and Murphy (1992) period has a good out of sample fit into the 1988-2008 period instead of showing a systematic and increasingly large over-prediction of the wage premium. The estimates show a much higher elasticity of substitution and a much smaller role for SBTC.

Section 2.4 uses a non-parametric approach to decompose the path of relative wages into supply and demand (SBTC) effects on relative prices, and changes in the relative per capita human capital of (within age and sex cell) college and high school graduates due to cohort effects. For 1975-2000, SBTC demand induced effects on the premium are required to explain the path of the wage premium but the magnitude is very sensitive to the estimate of σ. Using estimates incorporating the cohort effects only about 1 percent a year is required. Ignoring cohort effects substantially over-estimates the role of SBTC in explaining the increase in the wage premium in the 1975-2000 period.

Section 2.5 extends the analysis to the disaggregated canonical model introduced by Card and Lemieux (2001) to explain the age pattern in the college premium that is inconsistent with the results from the standard model implemented with composition adjusted relative wages and supplies. Cohort effects are introduced into the disaggregated model via an augmented model similar to that specified for the aggregate case. These effects again play a role similar to SBTC. The estimates of the basic and augmented versions of the model show that the use of composition adjusted measures again over estimates SBTC and under-estimates the elasticity of substitution across skill, but in addition it under-estimates the elasticity of substitution across age.[5] This substantially reduces the need for the introduction of imperfect substitutability across age to explain the age pattern for the college wage premium. Finally, Section 2.6 provides some conclusions.

2.2 The Canonical Model

The canonical model can be thought of in two forms - explaining relative factor prices (Katz and Murphy (1992), Card and Lemieux (2001), Autor, Katz and Kearney (2008)) or explaining factor prices and relative factor prices (Acemoglu and Autor (2011)). The most common form is explaining relative factor prices, using a CES production function without capital.

2.2.1 The Standard Two Skill Type Model

The canonical model assumes two skill types, high and low, that are imperfectly substitutable in production, and competitive labor markets. Following the notation of Acemoglu and Autor (2011), the total supplies of low and high skill are:

$$L = \int_{i \in \mathcal{L}} l_i di$$

and

$$H = \int_{i \in \mathcal{H}} h_i di$$

[5]Carneiro and Lee (2011) also show a much higher elasticity of substitution across age results in their framework when changes in the relative quality of college and high school graduates is taken into account instead of using simple composition adjustment.

where l_i (h_i) are the inelastically supplied efficiency units for (heterogeneous) worker $i \in \mathcal{L}$ ($\in \mathcal{H}$).The production function is CES:

$$Y = [(A_L L)^{\frac{\sigma-1}{\sigma}} + (A_H H)^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}} \tag{2.1}$$

The basic parameters are A_L and A_H, which scale the skills and set the technology and $\sigma \in [0, \infty)$, the elasticity of substitution.[6] Factor augmenting technical change is captured by changes over time in A_L and A_H.

The competitive labor market assumption implies that firms will set the value of the marginal product of L equal the *unit* wage for low skill (i.e. payment for one unit of L):

$$\frac{\partial Y}{\partial L} = A_L^{\frac{\sigma-1}{\sigma}} [(A_L L)^{\frac{\sigma-1}{\sigma}} + (A_H H)^{\frac{\sigma-1}{\sigma}}]^{\frac{1}{\sigma-1}} L^{\frac{-1}{\sigma}} = w_L \tag{2.2}$$

Similarly, for H:

$$\frac{\partial Y}{\partial H} = A_H^{\frac{\sigma-1}{\sigma}} [(A_L L)^{\frac{\sigma-1}{\sigma}} + (A_H H)^{\frac{\sigma-1}{\sigma}}]^{\frac{1}{\sigma-1}} H^{\frac{-1}{\sigma}} = w_H \tag{2.3}$$

Combining equations (2.2) and (2.3) and taking logs yields the relative demand function:

$$ln(H/L) = (\sigma - 1)ln(A_H/A_L) - \sigma ln(w_H/w_L) \tag{2.4}$$

The demand curve has an intercept (at equal factor prices), $(\sigma - 1)ln(A_H/A_L)$, that may shift over time due to SBTC, i.e. changes over time in $ln(A_H/A_L)$, and a slope, $-\sigma$, with respect to the relative prices. Equation (2.4) may be re-arranged to yield the skill premium equation:

$$ln\omega = ln(w_H/w_L) = \frac{\sigma - 1}{\sigma} ln(A_H/A_L) - \frac{1}{\sigma} ln(H/L) \tag{2.5}$$

[6]There is usually a distribution parameter δ and $(1 - \delta)$ in the CES which is combined in the A's for simplicity.

Re-writing this as:

$$ln\omega = \frac{1}{\sigma}[(\sigma - 1)ln(A_H/A_L) - ln(H/L)],$$

makes it clear that in an era of secular increase in the relative skill supply, the skill premium will increase or decrease depending on whether the relative demand shifts at a faster or slower rate than the relative supply. This is often characterized as a race between education (supply shifts) and technology (demand shifts).[7] As emphasized in Goldin and Katz (2007), in analyzing the effect of technological change on the premium, a key parameter in equation (2.5) is the elasticity of substitution, σ. The effect of technological change on the skill premium is given by the combination of the shift in demand, $(\sigma - 1)ln(A_H/A_L)$, for a given change in $ln(A_H/A_L)$, which is increasing in σ, and the effect of a given shift in demand on the premium given the inelastic supply curve, which is decreasing in σ. The overall effect is decreasing in σ. Intuitively, as skilled and unskilled workers become closer substitutes, the skill premium is less sensitive to any change in relative supplies and only modest skill biased technological change (SBTC) induced demand shifts are needed to prevent any decline in the skill premium.

2.2.2 Relative Prices, Relative Wages and the Canonical Model

The unit wages, w_H and w_L, in the canonical model are prices, which may be different from composition adjusted wages, and the L and H in the canonical model are the true quantities which may be different from the composition adjusted quantities. In this section we revisit the canonical model with an explicit recognition of potential differences between relative prices and relative composition adjusted wages, allowing for average quantity changes within skill type due to cohort effects. These cohort effects are due to time varying selection effects in who goes on to higher education, and to secular technological change in

[7] See, for example, Acemoglu and Autor (2011) and Goldin and Katz (2007) who attribute the first use of the phrase to Tinbergen (1974).

human capital production.[8] The canonical model as a model of relative price determination may be estimated directly using the prices and quantities from BR. However, an important focus of interest in the literature has been the path of relative composition adjusted wages, so in this section we specify an augmented canonical model to explain the path of relative composition adjusted wages as well as relative prices.

The augmented model retains the two factor structure. Let L and H be the quantities of low and high skill as before, but let these quantities differ from "composition adjusted" L_c and H_c quantities used in the standard implementation of the canonical model such that $L = B_L L_c$ and $H = B_H H_c$ where B_L and B_H capture the cohort effects of Bowlus and Robinson (2012) due to technological change in human capital production and selection effects. This introduces a distinction between prices (unit wages) and (composition adjusted) wages. The composition adjustment uses predefined "cells", based on schooling, experience and sex, to represent the heterogeneity of workers within skill type, i.e. the heterogeneity in l_i and h_i. The method assumes that, for each skill type, within cell the efficiency units of a person hour are fixed over time. Alternatively, if there remains some heterogeneity even within cell the method assumes that the efficiency units of the average person hour within the cell is constant over time. Thus, the composition adjusted quantity for the low skill type in time t is given by:

$$L_{ct} = \sum_{j=1}^{J} L_{jct} = \sum_{j=1}^{J} n_{jt} l_j \tag{2.6}$$

where for the low skill type there are J cells, L_{jct} is total composition adjusted efficiency units in cell j at time t, n_{jt} is the number of person hours in cell j at time t, and l_j is the fixed over time (average) efficiency units of a person hour in cell j. Similarly, for the high

[8] The technological change in human capital production is assumed to be always positive for the high skill because of the advance of knowledge, but may be zero or negative for the low skill reflecting progress or regress in the school system. The selection effects are governed by the size of the ability-education level correlation and the cohort fraction of high and low skill. For more details see BR.

skill type:

$$H_{ct} = \sum_{k=1}^{K} H_{kct} = \sum_{k=1}^{K} n_{kt} h_j \tag{2.7}$$

where for the high skill type there are K cells, H_{kct} is total composition adjusted efficiency units in cell k at time t, n_{kt} is the number of person hours in cell k at time t, and h_k is the fixed over time (average) efficiency units of a person hour in cell k.

The B_L and B_H terms measure the average number of units of L or H supplied by a (composition adjusted) unskilled or skilled worker hour. These terms may vary over time due to cohort effects. In particular, if l_j and/or h_j vary over time due to cohort effects, the B_L and B_H terms measure this as a deviation between the composition adjusted quantities, L_{ct} and H_{ct}, that assume l_j and h_j are fixed, and the true quantities L_t and H_t that allow l_j and h_j to vary over time. Denote total payments to unskilled as W_L. By definition, the total payment is the product of the price, w_L and the quantity, $L = B_L L_c$, i.e. $W_L = w_L B_L L_c =$. Similarly, $W_H = w_H B_H H_c$. Hence, given the composition adjusted quantities, L_c and H_c, the implied composition adjusted wages, given total wage payments, are: $w_L^c = w_L B_L = (W_L/L_c)$ and $w_H^c = w_H B_H = (W_H/H_c)$. Thus B_L and B_H are both the ratio of the composition adjusted wage and the price (unit wage) for each type and the inverse of the ratio of the composition adjusted quantity and the 'true' quantity for each type.

In the first order conditions (equations (2.2) and (2.3)) w_L and w_H are as before the prices (unit wages) for L and H.[9] The production function is the same as before but in terms of the composition adjusted quantities and the additional parameters, equation (2.1) is re-written:

$$Y = [(A_L B_L L_c)^{\frac{\sigma-1}{\sigma}} + (A_H B_H H_c)^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}},$$

[9]The earnings, and hence period wage, of low skilled worker i are given by the product of the unit price and the quantity l_i, but this quantity is no longer the same over time for a low skill worker of a given age and education, so the period wage for a low skill worker of a given age and education is no longer the same over time as the price.

and equation (2.5) may be re-written:

$$ln\omega = ln(w_H/w_L) = \frac{\sigma - 1}{\sigma} ln(A_H/A_L) - \frac{1}{\sigma} ln(B_H/B_L) - \frac{1}{\sigma} ln(H_c/L_c) \tag{2.8}$$

Alternatively, generating the first order conditions in composition adjusted wages and quantities, equation (2.5) may be re-written:

$$ln\omega_c = \frac{\sigma - 1}{\sigma} ln(A_H/A_L) + \frac{\sigma - 1}{\sigma} ln(B_H/B_L) - \frac{1}{\sigma} ln(H_c/L_c) \tag{2.9}$$

where $\omega_c = \frac{w_{H_c}}{w_{L_c}}$ is the relative composition adjusted wage. Note that in equation (2.9), the term $ln(B_H/B_L)$ plays exactly the same role in determining the composition adjusted wage premium, $ln\omega_c$, as the SBTC term, $ln(A_H/A_L)$. However, while the SBTC affects relative composition adjusted wages by shifting the relative demand, $ln(B_H/B_L)$ affects relative composition adjusted wages by incorporating the relative shift in true quantities supplied by the composition adjusted quantities, reflecting the within cell average efficiency unit changes. We refer to equation (2.9) as the augmented canonical model.

2.3 Empirical Implementation of the Canonical Model

Identifying the relative importance of demand and supply shifts in determining the path of the skill premium is complicated by the fact that, while various measures of the skill premium and the relative supply variable, are available, the variable relevant for demand intercept shifts or SBTC, $ln(A_H/A_L)$, is not. In addition, relative supply may not be exogenous.[10] The standard canonical literature has taken two main approaches to this. The first approach is to assume only that the observations are on the demand curve and use

[10] A further complication is that if technology can change over time in terms of $ln(A_H/A_L)$, why assume that σ is constant? This is examined further below.

a constant "reasonable" value of σ obtained from "the literature", together with equation (2.5) for various sub-periods of the data, together with observations on $ln(H/L)$ and $ln\omega$, to back out the implied $ln(A_H/A_L)$, and hence construct the effect of SBTC on the demand intercept, $(\sigma - 1)ln(A_H/A_L)$, or on the premium $\frac{\sigma-1}{\sigma}ln(A_H/A_L)$. (Goldin and Katz (2007), Autor, Levy and Murnane (2003)). The second approach assumes an exogenous supply and a parametric time trend for $ln(A_H/A_L)$, and uses a version of equation (2.5) incorporating this parametric time trend to estimate both σ and the shifting intercepts simultaneously.[11] (Katz and Murphy (1992), Card and Lemieux (2001), Autor, Katz and Kearney (2008), Acemoglu and Autor (2011).)[12] The standard literature uses composition adjusted measures as the proxies for relative prices (unit wages) and relative supplies, corresponding to $ln\omega_c$ and $ln(H_c/L_c)$. Within the framework of the previous section, this corresponds to estimating the augmented canonical model assuming $ln(B_H/B_L)$ is a constant.[13]

Identification in the augmented canonical model faces the same problems as in the basic canonical model: $ln(A_H/A_L)$ is not observed and the relative supplies may not be exogenous. The augmented canonical model may be estimated with the same relative wage and relative skill supplies series used in the standard literature, together with an estimated series for $ln(B_H/B_L)$. The two approaches used for the basic model may also be used for the augmented model. Assuming only that the observations are on the demand curve, given data on $ln\omega_c$, $ln(H_c/L_c)$, and $ln(B_H/B_L)$ and a value of σ from the literature, the implied effects of SBTC on the premium through demand shifts can be calculated. Alternatively, assuming exogenous supplies and a parametric time trend for SBTC, both σ and SBTC

[11] Edwards and Lange (2013) instrument relative supply with a measure of relative supply with average hours supplied fixed over time for each gender and education group. They find that OLS and IV results are very similar, and argue that endogeneity of relative supply is not a major concern in their analysis.

[12] Card and DiNardo (2002), noting the tautological nature of an unrestricted SBTC hypothesis, discuss a third approach in trying to get some proxy for the unobserved demand shifts, typically related to computer use. Krusell, *et al.* (2000) explore a capital-skill complementarity hypothesis and measures of capital over time to provide more direct measures of the demand shift.

[13] That is, for example, normalizing the ratio (B_H/B_L) to one, $ln\omega_c = ln\omega$, and $ln(H_c/L_c) = ln(H/L)$.

effects may be estimated simultaneously by estimating a version of equation (2.9) incorporating this parametric time trend. The dependent variable for the augmented model is the relative composition adjusted wage, $ln\omega_c$. Given equation (2.12), however, an alternative is to generate estimates using the basic canonical model, equation (2.5), directly with the BR prices and quantities to assess the demand and supply effects on the relative price path, $ln\omega$, and then to combine this with the path of $ln(B_H/B_L)$ to generate the relative wage path.

2.3.1 Data and Construction of the Variables

The data set is the same as that used in Bowlus and Robinson (2012). This uses the MCPS for the earnings years 1963-2008, applying top-code correction factors. The precise details of the sample construction are described fully in Bowlus and Robinson (2012). These data are very similar to those used by Acemoglu and Autor (2011) in their replication of Katz and Murphy (1992), and the extension to 2008. The standard literature brings the canonical model to the data by first constructing composition adjusted relative wages for high type (skilled) relative to low type (unskilled) workers, where their type is defined on the basis of their education level. Second, a composition adjusted ratio of the quantity of hours of skilled relative to unskilled workers is constructed using the cell structure described above, assuming l_j and h_j are constant over time, and making the composition adjustment according to the observed n_{jt} and n_{kt}. The standard literature begins with four education groups, dropouts, high school graduates, some college and college graduates and collapses them into the two skill "types", the high "college graduate" type and the low "high school graduate type". The most common definitions of the supplies allocate all college and 50% of some college to the high type and the remainder to the low type. However, in constructing the relative composition adjusted wages, only college graduate and high school graduate wages are used. We use the definitions specified in Autor, Katz and Kearney (2008) and used in Acemoglu and Autor (2011) to construct the proxies for "price" and "quantity" representative of the standard literature. As noted earlier, these correspond to $ln\omega_c$ and $ln(H_c/L_c)$ rather than the true relative prices and quantities, $ln\omega$ and $ln(H/L)$. However, since the standard literature assumes $ln(B_H/B_L)$ is a constant, the composition adjusted measures are equivalent to the "true" measures.

Carneiro and Lee (2011), BR, and Hendricks and Schoellman (2014) all provide evidence that $ln(B_H/B_L)$ is not constant, especially over the period of the rapidly rising skill premium. Carneiro and Lee (2011) and Hendricks and Schoellman (2014) attribute this primarily to variation in the quality of college graduate birth cohorts linked to enrolment rates. BR allow for both selection effects linked to enrolment rates, but also to secular improvement in human capital production functions, especially at the college level, corresponding to advancing knowledge. Our series for $ln(B_H/B_L)$ is based on BR and Autor, Katz and Kearney (2008). There are several ways to construct the series. From the earlier discussion, $ln(B_H/B_L)$ can be calculated from a comparison of estimates of the log quantity ratios, $ln(H/L)$ and $ln(H_c/L_c)$, or the log price ratios, $ln\omega$ and $ln\omega_c$. BR provides an estimated series for $ln\omega$, and given observed total wage payments, W_H and W_L, it also provides an implied estimate of $ln(H/L)$.[14] The two series are constrained by the identity that the product of the price and quantity add up to the total payments. The standard literature provides estimates of $ln\omega_c$ and $ln(H_c/L_c)$. However, these are obtained independently in the sense that neither is derived through the identity that the product of the price and quantity add up to the total payments, though in principle they should satisfy this property. In fact using the methods of the standard literature as represented by Autor, Katz and Kearney (2008), $ln\omega_c$ is obtained from data on college graduates and high school graduates only

[14]In order to fit in the two skill type framework of the canonical model, the four skill types in BR are also collapsed into two types, as in Autor, Katz and Kearney (2008), college and high school. The college and high school price series are used directly from BR. The quantity, H, is then simply the total expenditure (wage bill) on college type labor, W_H, divided by the college price, i.e. $H = \frac{W_H}{w_H}$. Similarly, the quantity $L = \frac{W_L}{w_L}$.

while the estimate for $ln(H_c/L_c)$ necessarily uses data on all four schooling groups.

2.3.2 Relative Prices, Wages, and Supplies: 1963-2008

Figure 2.1 shows the path of relative composition adjusted wages, $ln\omega_c$ and relative prices, $ln\omega$ over the 1963-2008 period.

Figure 2.1: Comparative Log Relative Price Series

The relative wage measure, $ln\omega_c$, is the composition adjusted relative wage as defined in the standard literature, represented here by Autor, Katz and Kearney (2008). The relative price series, $ln\omega$, is the relative price series from BR, normalized to same initial (1963) value as $ln\omega_c$. There is a substantial difference in the series. This reflects the evidence in BR and Carneiro and Lee (2011) that $ln(B_H/B_L)$ is not constant over time. There is some similarity in the two series, in that they both show a fall from the early to mid-1970s to the late 1970s, followed by a strong secular increase up to the late 1990s. Explaining the turn-around in relative prices from the falling period to the increase in the 1980s and 1990s in terms of a change in the path of relative supplies at the same point is considered as the key success of the standard canonical model. However, the magnitudes in the series are quite different, reflecting the time path of $ln(B_H/B_L)$ over the period. This suggests that the augmented canonical model may yield a different explanation for the path of composition adjusted relative wages than the standard model which treats composition adjusted relative wages as the true relative prices.[15]

The decomposition of the relative composition adjusted wage change (increased college premium) for the young (26-30) age group studied in Card and Lemieux (2001) into price and overall "within cell" quantity changes ($ln(B_H/B_L)$) evaluated for the young group) carried out in BR showed that over the 1975-2000 period, the relative price increase contributed only about one third of the composition adjusted relative wage increase. In Figure 2.1, $ln\omega_c$ represents the college premium averaged across all age groups. The difference in the path of $ln\omega_c$ and $ln\omega$ suggests that, again, overall relative "within cell" quantity changes ($ln(B_H/B_L)$) may play an important role. This is discussed in detail in Section 2.4 below.

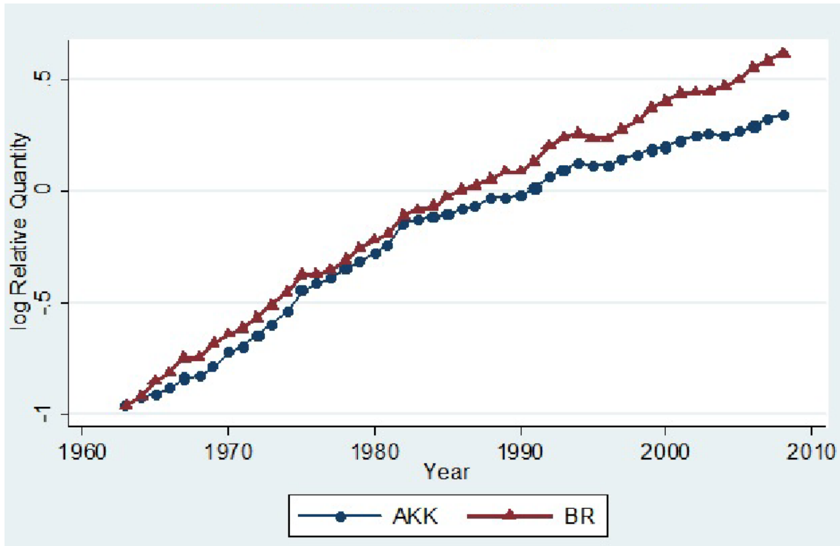
Figure 2.2 compares the two types of estimated relative supplies: the composition adjusted relative supplies, $ln(H_c/L_c)$, and $ln(H/L)$ obtained by dividing total relative wage payments by the BR relative price series.

The composition adjusted relative supplies, $ln(H_c/L_c)$, are calculated using the procedure of Autor, Katz and Kearney (2008) which assigns 50% of some college to H and 50% to L. The series for $ln(H/L)$ is calculated using a calculation of total wages which assigns 50% of some college to H and 50% to L.[16] Both measures show a strong increasing secular

[15] Edwards and Lange (2013), using the flat-spot method, also estimate skill price series for females. They find that female college-high school relative skill prices increased faster compared to males after the 1980s.

[16] Allocating the implied quantities of the some college group from the total expenditure on some college into the college and high school types requires some assumptions. If the total expenditure is divided half and half, that would assume that shares in a some college total wage were always one half from earnings on the college type human capital and one half on the high school type. This does not quite capture exactly the idea of each hour being a half hour of each type, since the college half hour would earn more. More importantly, it will change over time with relative prices, even if relative quantities were not supposed to have changed. However, since there is no obvious alternative, the BR quantities in this case are obtained simply by dividing

Figure 2.2: Comparative Relative Quantity Series: 50-50 Some College Assignment



trend in the relative supply of skill. In the context of the canonical model, in the absence of demand shifts in favor of H, this increased relative supply implies a decreased relative price ratio which is not observed in either relative price measure in Figure 2.1. The composition adjusted relative quantity measure, $ln(H_c/L_c)$, is the same as Acemoglu and Autor (2011) Figure 2 (p.1052), showing a flattening at 1982. The same pattern as Acemoglu and Autor (2011) is documented and commented on in Card and DiNardo (2002) who note that the supply index grew from 1967 to 1982 at a roughly constant rate of about 4.5% a year followed by a further period of constant growth between 1982 and 2000 at a much lower rate of about 2.0%. They also report that a regression of the supply index on a linear trend and a positive 1982 linear trend interaction has an R2 of 0.997[17] A similar fit occurs for $ln(H_c/L_c)$ in Figure 2.2. The separate period slopes for 1963-1982 and 1982-2008 are .0437 and .0191, respectively, and a regression for the whole period has $R^2 = .997$ with a

the relevant total wage payments by the relevant price series, where total wage payments to some college are divided 50-50 between the two groups.

[17]Card and DiNardo (2002), p752.

slope declining from .0451 before the break to .020 after the break. The BR ratios, $ln(H/L)$, also show a flattening, but the change is much less. A regression for the whole period has $R^2 = .998$ with a slope declining from .0442 before the break to .0279 after the break. The supply slowdown is significantly less for $ln(H/L)$.

2.3.3 Estimates from Parametric Canonical Models

The estimated skill ratio (Figure 2.2) has increased. In the canonical model, this would have reduced the skill premium in the absence of demand shifts. However, the estimated skill premium (Figure 2.1) has increased ($ln\omega_c$) or remained roughly the same ($ln\omega$) over time. To account for the secularly increasing skill premium as measured by a composition adjusted relative wage, $ln\omega_c$, during a period of a secularly increasing relative skill supply, the standard implementation of the canonical model assumes SBTC, i.e. increasing $ln(A_H/A_L)$ over time that produces a relative demand shift that is sufficient to outweigh the relative supply shift. An assumption has to be made regarding the time trend for $ln(A_H/A_L)$ since it is not observed. The original assumption in the canonical model (following Tinbergen) is that skill biased technological change follows a linear trend, $ln(A_H/A_L)_t = \gamma_0 + \gamma_1 t$. The estimating equation in the standard literature, assuming exogenous supplies, follows from imposing this trend specification and setting $ln(B_H/B_L) = 0$ in equation (2.9), yielding:

$$ln\omega_{ct} = \frac{\sigma - 1}{\sigma}\gamma_0 + \frac{\sigma - 1}{\sigma}\gamma_1 t - \frac{1}{\sigma} ln(H_c/L_c)_t \tag{2.10}$$

Replicating Katz and Murphy (1992) for the 1963-1987 period, Acemoglu and Autor (2011) obtain the result:

$$ln\omega_{ct} = k + 0.027t - 0.612 ln(H_c/L_c)_t$$

This captures well the sharp reversal of the trajectory of the premium coinciding with the deceleration in the growth of college relative supply in the late 1970s. The implied elasticity of substitution is $\frac{1}{.0612} \simeq 1.634$. SBTC increases the premium by 2.7% a year, implying an annual relative demand shift due to SBTC of 4.4%. Columns 1 and 3-5 of Table 2.1 report the results for the replication by Acemoglu and Autor (2011) of Katz and Murphy (1992), and their extension to 2008 using our data set. We follow the procedure described in Acemoglu and Autor (2011) for construction of the variables and apply their sample selection criteria. The results are almost identical to the reported results in Acemoglu and Autor (2011), Table 8. Comparing columns 1 and 3 shows the marked difference in the estimates for the elasticity of substitution and for the time trend using the extended period compared to the original Katz and Murphy (1992) period. One result of this is the poor out of sample fit using the parameters estimated on the original period. Figure 2.3 shows the problem highlighted in Autor, Katz and Kearney (2008). The prediction systematically deviates from the data, predicting a much larger increase in the premium after the 1963-1987 sample period than actually occurs in the data.

Inspection of columns 1 and 3 in Table 2.1 shows that a linear time trend imposed over the whole period results in a much higher elasticity of substitution (2.955 vs. 1.598) and a much lower time trend (1.64% vs. 2.74%). Autor, Katz and Kearney (2008) and Acemoglu and Autor (2011) examined possible amendments to the canonical model that might allow it to fit the data for the whole period. Columns 4 and 5 show identical results on our data. Column 4 allows for a break in the time trend at 1992, and column 5 allows for a more flexible time trend throughout the period. This different specification of the time effect does allow a relatively stable elasticity of substitution over the whole period, but the required time effects imply that the relative demand for college workers decelerated in the 1990's which "does not accord with common intuitions regarding the nature or pace of

Table 2.1: Canonical Model: Composition Adjusted Prices and Quantities

	1963-1987	1988-2008		1963-2008	
$ln(H_c/L_c)$	-0.6258	0.2853	-0.3384	-0.6454	-0.5590
	(4.86)	(1.96)	(7.88)	(9.87)	(5.95)
time	0.0274	0.0023	0.0164	0.0285	0.0197
	(5.08)	(0.83)	(12.61)	(11.69)	(3.58)
$time^2$ x 100	.	.	.	.	0.0358
	.	.	.	.	(2.93)
$time^3$ x 1000	.	.	.	.	-0.0069
	.	.	.	.	(4.37)
After 1992	.	.	.	-0.0102	.
	.	.	.	(5.45)	.
σ	1.598	-3.505	2.955	1.549	1.789
Demand Shift	0.0438	-0.0080	0.0486	.	.
Demand Shift 1963-1992	.	.	.	0.0442	.
Demand Shift 1992-2008	.	.	.	0.0284	.
R^2	0.5680	0.9480	0.9348	0.9618	0.9600
TSS	0.0231	0.0466	0.3930	0.3930	0.3930
N	25	21	46	46	46

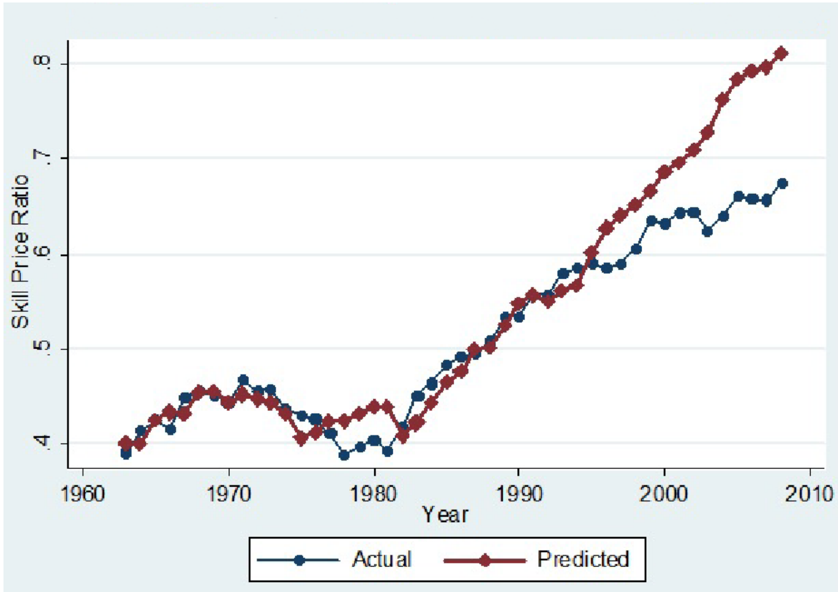
Notes: Absolute value of t-statistics in parentheses

technological change occurring in this era."[18]

The exact role of SBTC and σ on the premium path is complicated by the absence of a direct measure of SBTC, and the consequent identification problem. The identification approach using the basic canonical model reported in Table 1 that estimates both σ and SBTC simultaneously is to assume exogenous supplies and a specific parametric form for SBTC that allows SBTC to change over time, but not σ. The results in column 2 of Table 1 highlight the potential problems with this identification strategy. Estimating the model on the post 1987 data yields the wrong sign for σ and no SBTC. In fact, extending the sample backwards all the way to 1980, producing a larger sample size than the original 1963-1987 period, just makes things worse, with a larger and more statistically significant negative value for σ. Unless the sample period is extended far enough back to cover both sides of the "break" in the trend for the relative supplies, the estimate of σ will have the wrong

[18] Acemoglu and Autor (2011), p. 1109.

Figure 2.3: Predictions from the 1963-1987 Basic Canonical Model



sign, and once this period is included the estimate of σ will be highly sensitive to the exact sample composition. There is a tradeoff in fitting the entire period in terms of a higher σ and a smaller SBTC induced increase in the premium. The choice in columns 4 and 5 is to fit the period with lower σ and a more flexible, mostly higher SBTC induced increase in the premium. For the size of the SBTC induced demand shift this choice is not so critical, but the estimated size of the SBTC induced increase in the premium is very sensitive to this choice.[19]

In the canonical model, σ and SBTC are the relevant parameters for the interaction of demand and supply in determining the path of relative prices, $ln\omega$. The standard estimates of σ and SBTC are obtained using $ln\omega_c$ and $ln(H_c/L_c)$ rather than $ln\omega$ and $ln(H/L)$. They are, therefore, sensitive to the implicit maintained assumption that $ln(B_H/B_L)$ is constant

[19]While the estimates of σ and the time trend are very different in columns 1 and 3, the implied SBTC induced demand shift is quite similar. That is, in column 3 the SBTC induced demand shift $((\sigma-1)ln(A_H/A_L))$is similar, but the higher estimated elasticity compared to column 1 converts this into a smaller SBTC induced increase in the premium $(\frac{\sigma-1}{\sigma}ln(A_H/A_L))$.

over time. Alternative estimates using the parametric canonical model may be obtained by using $ln\omega$ and $ln(H/L)$ in the basic canonical model directly, or by estimating the augmented model with $ln\omega_c$ and $ln(H_c/L_c)$, relaxing the assumption that $ln(B_H/B_L)$ is constant over time. The estimating equation for the augmented canonical model, assuming exogenous supplies, follows from imposing the time trend specification for $ln(A_H/A_L)$ in equation (2.9), but not setting $ln(B_H/B_L) = 0$. The estimating equation is thus:

$$ln\omega_{ct} = \frac{\sigma - 1}{\sigma}\gamma_0 + \frac{\sigma - 1}{\sigma}\gamma_1 t + \frac{\sigma - 1}{\sigma} ln(B_H/B_L) - \frac{1}{\sigma} ln(H_c/L_c)_t \tag{2.11}$$

Using the direct, or augmented approach, the main results are similar. They both show much higher estimates of σ and lower estimates of SBTC. The main estimates using the direct and augmented approaches are presented in Table 2.2.[20] The direct approach uses $ln\omega$ and $ln(H/L)$. As shown in Figure 2.1, there is much less variation in the relative price, $ln\omega$, than in the relative wage, $ln\omega_c$, and the slope change in the early 1980s in relative supply, $ln(H/L)$, is smaller than in $ln(H_c/L_c)$. Using the direct approach there is no longer a problem with the wrong sign for σ in either sub-period. In both sub-periods, and for the whole period the point estimates are quite similar, though in the post 1987 period the estimate is imprecise. The estimates for σ are around double those in Table 2.1.[21] Using the augmented model, the dependent variable is $ln\omega_c$, as in Table 2.1, but again the estimates for σ are around double those in Table 2.1.[22] Similarly, in both approaches, the estimates

[20]Edwards and Lange (2013) also estimate the canonical model using skill prices estimated using the flat-spot method over the 1963-2011 period. They use gender and education-specific labour aggregates in their CES production function. Our results are very similar to their results for males. They find that relative demand for college labour grew at a rate of around 1% for males, and around 2% for females. They also find that the demand for female labour relative to males have grown at a rate of around 1-2%.

[21]All four price series (dropouts, high school graduates, some college and college graduates) reported in BR, but especially the high school and college graduates, were highly correlated, deviating from one-another only temporarily over the entire 1963-2008 period, suggesting that the different types of human capital are highly substitutable.

[22]Unlike the direct approach, however, the augmented model still has the wrong sign for σ when estimation is done for any period that does not include several years on both sides of the break in the trend for the supplies in the early 1980s.

for SBTC are much lower than in Table 2.2.1.

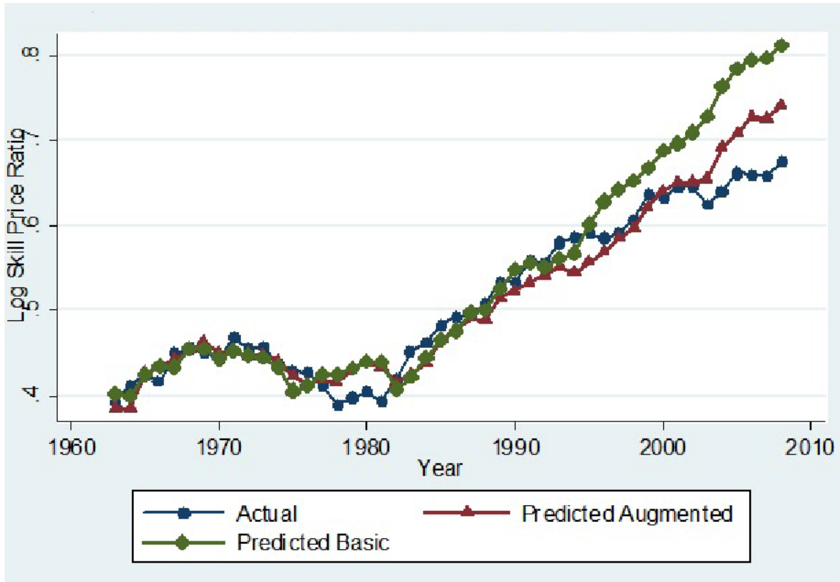
Table 2.2: Alternative Canonical Model Estimates

	Direct $ln\omega$			Augmented Model $ln\omega_c$			
	1963-1987	1988-2008	1963-2008	1963-1987	—- 1963-2008 —-		
$ln(H/L)$	-0.1750	-0.2613	-0.2616	.	.	.	.
	(1.28)	(1.29)	(3.04)	.	.	.	.
$ln(H_c/L_c)$	.	.	.	-0.3008	-0.1774	-0.2054	-0.1955
	.	.	.	(1.41)	(2.12)	(1.93)	(6.02)
time	0.0074	0.0078	0.0043	0.0138	0.0098	-0.0006	.
	(1.29)	(1.40)	(0.89)	(1.54)	(2.99)	(0.10)	.
$time^2$ x 100	.	.	0.0422	.	.	0.0574	0.0582
	.	.	(4.76)	.	.	(5.27)	(8.48)
$time^3$ x 1000	.	.	-0.0069	.	.	-0.0092	-0.0092
	.	.	(6.34)	.	.	(6.73)	(7.99)
$ln(B_H/B_L)*$	.	.	.	0.4844	0.4148	0.6598	0.6776
	.	.	.	(1.86)	(2.21)	(4.75)	(6.58)
σ	5.714	3.828	3.822	3.235	5.636	4.868	5.115
F	.	.	.	2.07	11.16	1.57	1.63
$Prob > F$	.	.	.	0.1645	0.0018	0.2175	0.2084
R^2	0.0699	0.1209	0.8307	0.6292	0.9415	0.9744	0.9744
TSS	0.0040	0.0092	0.0403	0.0231	0.3930	0.3930	0.3930
N	25	21	46	25	46	46	46

Notes: Absolute value of t-statistics in parentheses

One result of the lower time trend and higher σ in the augmented model is a much improved out of sample fit. For the augmented model the out of sample prediction uses the coefficients estimated on the 1963-1987 period reported in column 4 in Table 2.2 to predict the premium, $ln\omega_c$. Figure 2.4 shows a comparison of the out of sample fit for both the basic and augmented models with a simple linear trend. The prediction from the augmented model is close for all but the last few periods. The direct approach model predicts the skill price ratio $ln\omega$ rather than the wage premium, $ln\omega_c$. Figure 2.5 shows the fit for the direct approach for the whole period based on the coefficients in Table 2.2, column 7. The direct approach can also be used to do an out of sample prediction of the wage premium by using the coefficients estimated on the 1963-1987 period reported in column 1 in Table 2.2 to predict the relative price, $ln\omega$, and calculating a predicted relative premium, $ln\omega_c$, as the

Figure 2.4: Comparative Predictions from the 1963-1987 Canonical Models

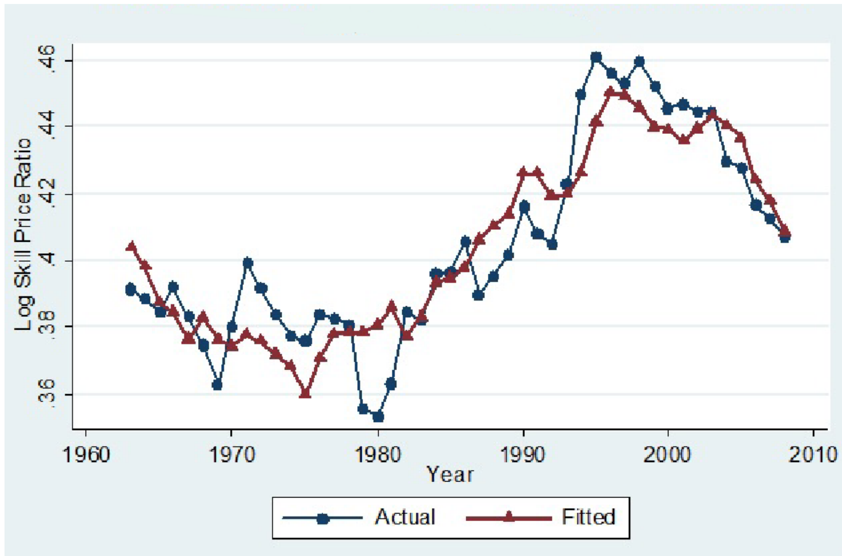


sum of the predicted relative price and $ln(B_H/B_L)$. The result is reported in Figure 2.6 and shows a very close fit.

There is a potential bias issue using the direct approach since the right-hand-side variable, $ln(H/L)$, is obtained by dividing the total wage payments ratio by the BR price series, $ln\omega$, which is the dependent variable. Since the BR price series are likely measured with error, the right-hand-side variable will be correlated with the measurement error. If the measurement error is of the classic form, the effect of the measurement error in this case is to bias the estimate of σ to 1.[23] In fact, the estimate of σ using the direct approach is similar to the estimate from the augmented model, and both are much larger than the estimate in the standard literature. Carneiro and Lee (2011) noted that when they took into account the within cell quality changes, their estimates for the elasticity of substitution across age in a framework similar to Card and Lemieux (2001) was much higher than when conventional composition adjustment was used. Given time variation in $ln(B_H/B_L)$, $ln\omega_c$ may be

[23]See the Appendix for more details.

Figure 2.5: Fitted and Actual Log Relative Price Ratio, 1963-2008 BR Prices and Quantities

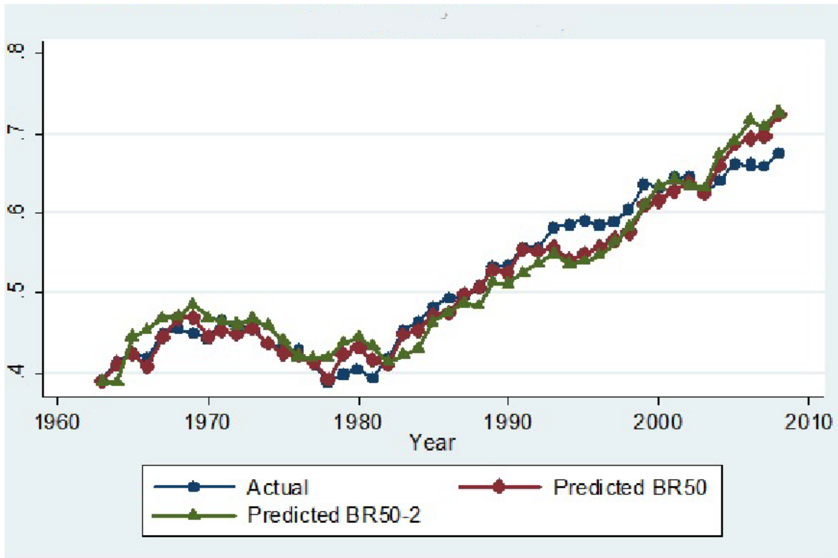


viewed as a price series with measurement error. Suppose the BR price series are the true price series, then the difference, $ln(B_H/B_L)$ is the measurement error in the standard literature, which may bias the estimated σ to 1. This can account for the higher estimates for σ compared to the standard literature reported here and in Carneiro and Lee (2011) when variation in $ln(B_H/B_L)$ is taken into account.

2.4 Relative Wages, Relative Prices, Skill Supplies and SBTC

In the canonical model, the path of supply and (SBTC induced) demand determine the path of relative prices, $ln\omega$. In the standard literature where the absence of time variation in $ln(B_H/B_L)$ is implicitly assumed, this is the same as the composition adjusted wage premium, $ln\omega_c$. More generally, however, the overall path of the relative wage premium, ω_c, can be decomposed into the path of relative prices, ω, and the path of relative aver-

Figure 2.6: Predicted Premium from the 1963-1987: Direct Approach, BR Prices and Quantities



Note: BR50 uses Log B ratio derived from the two price series; BR 50-2 uses the Log B ratio derived from the two quantity series

age quantity adjustments of the two skill types, $ln(B_H/B_L)$, due to cohort effects operating within cells. The path of relative prices, ω is determined, as in the standard literature, by the "race" between the relative supply growth and the SBTC, resulting in a net demand-supply effect that is positive if SBTC wins the race. This net demand-supply effect can then be further decomposed into the path of the (positive) demand (SBTC) effects, $(\frac{\sigma-1}{\sigma}ln(A_H/A_L))$, and the (negative) supply effects, $(-\frac{1}{\sigma}ln(H/L))$.

$$ln\omega_c = ln\omega + ln(B_H/B_L) = [\frac{\sigma-1}{\sigma}ln(A_H/A_L) - \frac{1}{\sigma}ln(H/L)] + ln(B_H/B_L) \qquad (2.12)$$

2.4.1 Non-parametric Decomposition of the Wage Premium

In this section we decompose the path of the wage premium into the paths of three effects on the premium: SBTC induced demand, relative skill supply, and $ln(B_H/B_L)$, and assess their relative importance. Given the potential problems arising from the approach used in Tables 1 & 2 where σ and SBTC are simultaneously estimated in a parametric framework with exogenous supplies, some authors have use an alternative approach that imposes no parametric form for SBTC, or exogenous supplies, but instead "backs out" values for SBTC, assuming a value for σ and that the observed data are on the demand curve.[24] In this section we follow this approach. The main problem is that a separate estimate of σ is required. The decomposition of the relative wage premium, ω_c, into the path of the net demand-supply effect, i.e. relative prices, ω, and the path of relative average quantities of the two skill types, $ln(B_H/B_L)$ does not depend on the estimate of σ. It just requires an estimate of $ln(B_H/B_L)$ and the composition adjusted wage premium, ω_c. However, the further decomposition of the path of the net demand-supply effect reflected in the relative prices into the path of the (positive) demand (SBTC) effects, $(\frac{\sigma-1}{\sigma}ln(A_H/A_L))$, and the (negative) supply effects, $(-\frac{1}{\sigma}ln(H/L))$, is sensitive to the estimate of σ.

Table 2.3 reports the results of the decomposition over the sub-period 1975-2000 when the large premium increase mainly occurred. The results are as follows. The log wage

Table 2.3: Decomposition of the Increase in the Log Wage premium: 1975-2000

	Augmented Model		Standard Model	
	1975-2000			
Δ Premium	.2021		.2021	
Δ Relative Skill Supply	.7829		.6452	
Δ Log B	.1377		.0000	
Net Demand and Supply Effect	.0643		.2021	
	Demand	Supply	Demand	Supply
σ = 1.8	0.4993	-0.4349	0.5605	-0.3584
σ = 3.0	0.3253	-0.2610	0.4171	-0.2151
σ = 4.0	0.2601	-0.1957	0.3634	-0.1613

premium increased by .2021 log points. The composition adjusted log relative supply, $ln(H_c/L_c)$, increased by .6452 log points and the log relative supply adjusting for the within

[24] See, for example, Goldin and Katz (2007) and Autor, Levy and Murnane (2003).

cell changes due to cohort effects, $ln(H/L)$ increased by .7795 log points. Thus, there would have been a potentially large decline in the wage premium without the counterbalance of SBTC and an increase in $ln(B_H/B_L)$. In fact, $ln(B_H/B_L)$ increased by .1377 log points, so this accounts for two thirds of the premium increase over 1975-2000. Table 2.3 reports the decomposition using both the augmented and standard canonical models. The augmented model has a first level decomposition into a net demand and supply (or relative price) effect and an effect due to $ln(B_H/B_L)$. The net demand and supply effect is invariant to the choice of σ. In both the augmented and basic model the net demand and supply effect is decomposed into the separate demand (SBTC) effects and supply effects; this decomposition is sensitive to the choice of σ. The effect on the premium of the secular increase in relative skill supply increase depends on σ. With a large σ, there is less downward pressure on the premium and hence, a smaller magnitude of SBTC is needed to offset it. This is the intuition behind the dependence of the relative importance of the implied SBTC on the premium change: it is relatively less important when σ is high.

In the augmented model framework the net effect of the demand and supply is to increase the premium by .0643 log points. There is a large increase in relative supply of .7829 log points which has a negative effect on the premium ranging from -.4349 for $\sigma = 1.8$ to -.1957 for $\sigma = 4.0$. These supply effect magnitudes are associated with implied SBTC induced demand effect magnitudes ranging from .4993 to .2601 log points. In the standard canonical model, which sets $ln(B_H/B_L) = 0$, the net demand-supply effect is to increase the premium by .2021 log points. This is much larger than for the augmented model since it attributes the $ln(B_H/B_L)$ effect of .1377 log points to the net demand-supply effect. This, in turn, affects the magnitudes of the separate demand and supply effects in the decomposition of the net effect. In the standard model the increase in relative supply is given by the increase in $ln(H_c/L_c)$ which is .6452 points, compared to the .7829 log point increase for $ln(H/L)$ in the augmented model. This translates into smaller negative supply effects on the premium in the standard model ranging from -.3584 for $\sigma = 1.8$ to -.1613 for $\sigma = 4.0$. However, the estimated SBTC induced demand effects on the premium are larger in the standard model because of the much larger estimated net demand-supply effect that results from attributing the $ln(B_H/B_L)$ effect of .1377 log points to the net demand-supply effect.

In summary, for 1975-2000, SBTC demand induced effects on the premium are required for all values of σ to explain the path of the wage premium but the magnitude is very sensitive to the estimate of σ. For $\sigma = 4.0$, as estimated in the augmented model, only .26 log points are required from SBTC over the 25 year period, or about 1 percent a year. By comparison, the increase in $ln(B_H/B_L)$ contributed .1377 log points to the premium over this period. In the combined effect of the $ln(B_H/B_L)$ changes and the SBTC induced effects that more than offset the negative supply effect, the $ln(B_H/B_L)$ changes contribute one third of the combined effect. Thus, ignoring the changes in $ln(B_H/B_L)$ substantially over-estimates the role of SBTC in explaining the increase in the wage premium in the 1975-2000 period.

2.4.2 The Time Path of SBTC and the Elasticity of Substitution

The elasticity of substitution is an important parameter in the canonical model. As shown in the previous section, the importance of SBTC is very sensitive to the value of σ. It also plays a role in the estimated time path for SBTC. As noted earlier, one criticism of the standard canonical model is that in order to fit the whole period, 1963-2008, it is necessary to relax the simple linear time trend, but the consequence of this is to estimate a much smaller SBTC effect in the 1990s than in the earlier periods, which "does not accord with common intuitions regarding the nature or pace of technological change occurring in this era."[25] To avoid problems of functional form and identification, we re-visit this question following

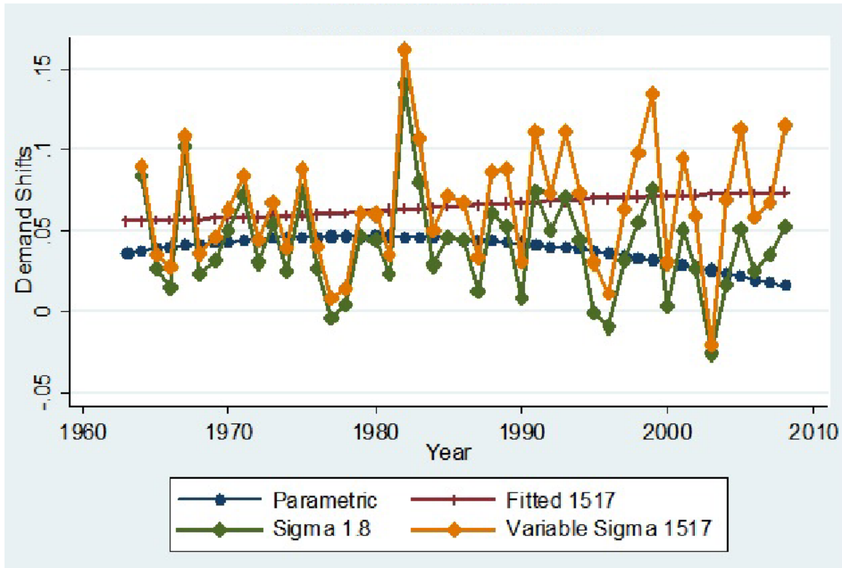
[25] Acemoglu and Autor (2011), p. 1109.

the non-parametric approach used in the decomposition, but with further emphasis on the role of σ.

An identification issue for the SBTC path arises from the presumed constancy of σ throughout the period in the standard approach to the basic model. It has been suggested that there has in fact been an increase in σ over time. More mechanically, using the AKK definitions with 50-50 assignment of some college to the two groups, and an increase over time in the share of some college, the two groups are likely to have become more similar by definition, even if the elasticities between each of the subgroups stayed the same over time. This is strongly reinforced by a dramatic decline in the share of dropouts in the high school group, which are presumably least substitutable for college, and an increase in the some college component which is presumably more substitutable for college.[26] Allowing σ to increase over time has a significant effect on the implied time path for SBTC. The SBTC is a shift in the demand curve. Figure 2.7 shows the sensitivity of the time path of the implied shifts to a fixed or variable σ. Figure 2.7 plots the (noisy) non-parametric estimated shifts for a fixed σ of 1.8, together with predicted shifts from the parametric canonical model with a flexible time trend from column 5 in Table 2.1 where the estimate of σ is 1.8. This shows the implied decline through the 1980s and 1990s noted by Acemoglu and Autor (2011) as a problem for the canonical model. Figure 2.7 also plots the (noisy) implied non-parametric estimated shifts for a variable σ that increases from 1.5 to 3.3 at a constant rate over the period, 1963-2008, as well as fitted values of these shifts from a cubic regression. The variable σ reverses the time path of SBTC so that it increases throughout the period.

[26]Figure A.1 in the Appendix show the large changes in the share of dropouts in the high school aggregate and the share of some college in both the high school and the college graduate aggregates over time.

Figure 2.7: Comparison of Implied SBTC Demand Shifts: Basic Model, AKK50 Prices and Quantities



2.5 Imperfect Substitutability Across Age?

Acemoglu and Autor (2011) note that a significant feature of the data on wage premia that the basic canonical model is unable to address is the major variation by age. In particular, Card and Lemieux (2001) pointed out that in the period of a rapidly rising college wage premium, the increase was almost exclusively confined to the young age groups. In order to explore this age pattern within the framework of the canonical model approach, Card and Lemieux (2001) expanded the number of different types of labor input by introducing imperfect substitutability across age groups within the original two input "types", H and L. Their estimated age elasticities are in fact quite large, but are not too large to allow the model to go someway to reconciling differences in the wage premium path by age. However, this is not necessarily a problem for the canonical model when viewed as a model of relative prices rather than relative composition adjusted wages. The differences by age in the path of the college premium was examined in Bowlus and Robinson (2012). Their results showed that only one third of the increase in the college wage premium for the young college graduates was actually an increase in the relative price. This result suggests that the more parsimonious basic canonical model, with perfect substitutability across age groups may provide a reasonable approximation for the wage patterns as long as cohort effects on the relative per capita quantities by age are taken into account when predicting relative wages.

2.5.1 The College Wage Premium by Age and Experience

Card and Lemieux (2001), Figure 1, document the strong age pattern in the college premium, plotting the log wage gap at 5 year intervals between males with a college degree and those with a high school diploma for two age groups, 26-30 and 46-60. The differences are particularly strong for 1980-1995 where there is a large increase in the gap for the young group, but very little for the old group. Acemoglu and Autor (2011), Figure 21, plot an annual series of the log wage gap for two experience groups, 0-9 and 20-29 showing a much larger increase for the younger experience group over the 1980-1995 period. Using the MCPS data used in this chapter, BR reproduce the same pattern for the 26-30 age group as Card and Lemieux (2001) but argue that this is mainly due to particularly strong cohort effects in that period that cause a divergence between relative wages and relative prices. The 26-30 age group in 1975 corresponds to college graduates from the 1945-1949 birth cohorts. These are the cohorts with the largest fraction of college graduates, which implies both in BR and in Carneiro and Lee (2011), the largest negative selection effects on their per capita human capital. In BR, the subsequent cohorts of college graduates improve both because of positive selection effects as the fraction going to college decreases, but also because of secular technological improvement in the production of human capital.

The 26-30 age group in 1990 corresponds to college graduates from the 1960-1964 birth cohorts. The estimates in BR suggest a large difference in per capita human capital between these cohorts: enough to account for two thirds of the increase in the gap. By contrast, cohort effects are likely to be much weaker for the 46-60 age group. This age group corresponds to college graduates from the 1915-1929 birth cohorts for the 1975 data, compared to the 1935-1949 birth cohorts for the 1995 data. In the BR framework, these cohorts experienced negative selection effects as the college fraction increased, but positive secular human capital production function technology improvement effects that offset one another, unlike the young group where the positive technology effects are reinforced by the positive selection effects.

Figure 2.8: Log Wage Gap by Experience: Males

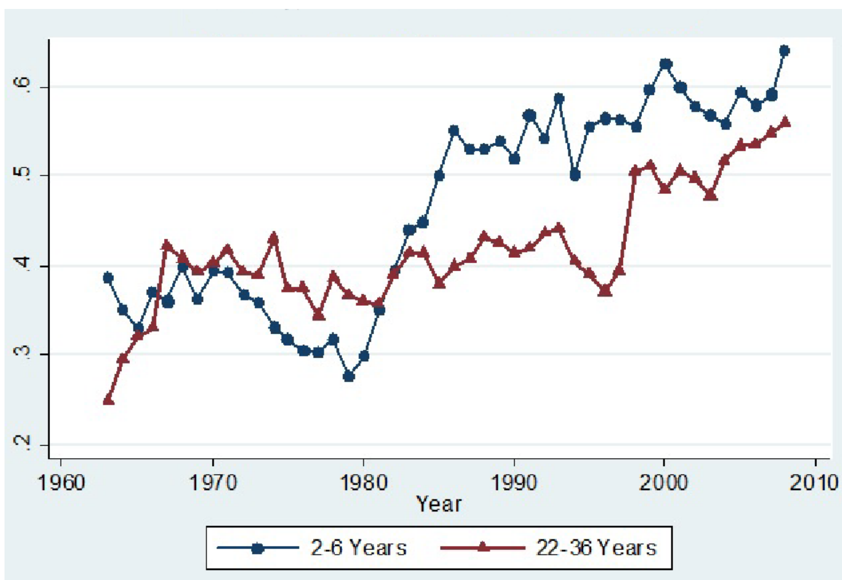


Figure 2.8 plots the wage gap by experience groups approximating the college age groups in the comparison with Card and Lemieux (2001) in BR, where the young group corresponds to the cohorts with the largest fraction of college graduates. The experience groups are 2-6 and 22-36. The plots are very similar to the plots in Acemoglu and Autor (2011), Figure 21 for experience groups 0-9 and 20-29. In this section we examine

the extent to which this pattern is consistent with a canonical model for skill prices with approximately perfect substitutability across age or experience groups.

2.5.2 Imperfect Substitutability Across Age in The Basic Model

Card and Lemieux (2001) allow for imperfect substitution between J age groups by re-defining the low (L) and high (H) type inputs as composites given by:

$$L = [\sum_j (\alpha_{Lj} L_j)^{\frac{(\sigma_A - 1)}{\sigma_A}}]^{\frac{\sigma_A}{(\sigma_A - 1)}} \tag{2.13}$$

and

$$H = [\sum_j (\alpha_{Hj} H_j)^{\frac{(\sigma_A - 1)}{\sigma_A}}]^{\frac{\sigma_A}{(\sigma_A - 1)}} \tag{2.14}$$

The wage premium for the high type for a given age group in general depends on both the composite ratio, (H/L), and the age-specific ratio, (H_j/L_j). The competitive labor market assumption implies that the *unit* wage for low skill age j (i.e. payment for one unit of L_j) is given by the value of the marginal product of L_j:

$$w_{Lj} = \frac{\partial Y}{\partial L_j} = \frac{\partial Y}{\partial L}\frac{\partial L}{\partial L_j}$$

Given:

$$\frac{\partial L}{\partial L_j} = \alpha_{Lj}^{\frac{(\sigma_A - 1)}{\sigma_A}} [\sum_j (\alpha_{Lj} L_j)^{\frac{(\sigma_A - 1)}{\sigma_A}}]^{\frac{1}{(\sigma_A - 1)}} L_j^{-\frac{1}{\sigma_A}} = \alpha_{Lj}^{\frac{(\sigma_A - 1)}{\sigma_A}} L^{\frac{1}{\sigma_A}} L_j^{-\frac{1}{\sigma_A}}$$

$$w_{Lj} = \frac{\partial Y}{\partial L}\alpha_{Lj}^{\frac{(\sigma_A - 1)}{\sigma_A}} L^{\frac{1}{\sigma_A}} L_j^{-\frac{1}{\sigma_A}} \tag{2.15}$$

Similarly,

$$w_{Hj} = \frac{\partial Y}{\partial H}\alpha_{Hj}^{\frac{(\sigma_A - 1)}{\sigma_A}} H^{\frac{1}{\sigma_A}} H_j^{-\frac{1}{\sigma_A}} \tag{2.16}$$

Using (2.5) above, the log premium for age group j is given by:

$$ln\omega_j = \frac{\sigma - 1}{\sigma} ln(\frac{A_H}{A_L}) - \frac{1}{\sigma} ln(\frac{H}{L}) + \frac{(\sigma_A - 1)}{\sigma_A} ln(\frac{\alpha_{Hj}}{\alpha_{Lj}}) + \frac{1}{\sigma_A}[ln(\frac{H}{L})] - \frac{1}{\sigma_A}[ln(\frac{H_j}{L_j})] \quad (2.17)$$

which, following the approach of Card and Lemieux (2002) can be written:

$$ln\omega_j = \frac{\sigma - 1}{\sigma} ln(\frac{A_H}{A_L}) - \frac{1}{\sigma} ln(\frac{H}{L}) + \frac{(\sigma_A - 1)}{\sigma_A} ln(\frac{\alpha_{Hj}}{\alpha_{Lj}}) - \frac{1}{\sigma_A}[ln(\frac{H_j}{L_j}) - ln(\frac{H}{L})] \quad (2.18)$$

where the coefficient on the log ratio of the aggregated supplies, $ln(H/L)$, provides an estimate of $\frac{1}{\sigma}$ and the coefficient on the deviation of the age group specific supplies from the aggregated supplies, $[ln(H_j/L_j) - ln(H/L)]$, provides an estimate of $\frac{1}{\sigma_A}$.

Card and Lemieux (2001), assume $ln(\alpha_{Hj}/\alpha_{Lj})$ is constant over time and take this to the data using the equation:

$$ln\omega_{jt} = \beta_0 + \beta_3 t + \beta_4 t^2 - \frac{1}{\sigma} ln(\frac{H}{L}) - \frac{1}{\sigma_A}[ln(\frac{H_j}{L_j}) - ln(\frac{H}{L})] + \delta_j + \eta_{jt}$$

where j indexes age groups. This allows for group specific intercepts but constrains the other coefficients to be the same for all groups. Acemoglu and Autor (2011), following Card and Lemieux (2001), estimate the same equation, replacing age groups with experience groups.[27]

The results for the US help to explain variation across age or experience groups in the evolution of the college premium, as reported in Card and Lemieux (2001). However, as noted above, a decomposition in BR of the age specific premium for the young college group that showed the largest premium increase yields the result that the increase was not,

[27] Card and Lemieux (2001) use age groups in their main Table III, but in their reporting of robustness results they also include a specification with experience. This affects the age range of the data used differentially for high school and college, but the basic pattern of results is similar. The results in Acemoglu and Autor (2011, Table 9) are similar to Card and Lemieux (2001) for the US, though the estimate of σ_A is smaller.

in fact, due mainly to a price effect but rather reflected the differential path of cohort effects on the relative quantities of human capital for young college graduates compared to high school graduates. Young college graduates had relatively large increases in their human capital compared to high school graduates over the 1975-1995 period compared to older college graduates relative to older high school graduates. This age pattern of the cohort effects suggests that an augmented version of the Card and Lemieux (2001) formulation should be estimated that incorporates these cohort effects.

2.5.3 Augmenting the Basic Model with Imperfect Substitutability Across Age

A natural way to incorporate the age-specific cohort effects is to replace the B_H and B_L parameters with age specific versions by re-writing (2.13) and (2.14) as:

$$L = [\sum_j (\alpha_{Lj} B_{Lj} L_{cj})^{\frac{(\sigma_A - 1)}{\sigma_A}}]^{\frac{\sigma_A}{(\sigma_A - 1)}} \tag{2.19}$$

and

$$H = [\sum_j (\alpha_{Hj} B_{Hj} H_{cj})^{\frac{(\sigma_A - 1)}{\sigma_A}}]^{\frac{\sigma_A}{(\sigma_A - 1)}} \tag{2.20}$$

The first order conditions using the composition adjusted wages are:

$$w_{L_{cj}} = \frac{\partial Y}{\partial L} \alpha_{Lj}^{\frac{(\sigma_A - 1)}{\sigma_A}} B_{Lj}^{\frac{(\sigma_A - 1)}{\sigma_A}} L^{\frac{1}{\sigma_A}} L_{cj}^{-\frac{1}{\sigma_A}}$$

and

$$w_{H_{cj}} = \frac{\partial Y}{\partial H} \alpha_{Hj}^{\frac{(\sigma_A - 1)}{\sigma_A}} B_{Hj}^{\frac{(\sigma_A - 1)}{\sigma_A}} H^{\frac{1}{\sigma_A}} H_{cj}^{-\frac{1}{\sigma_A}}$$

The augmented model is then:

$$ln\omega_{cj} = \frac{\sigma-1}{\sigma}ln(\frac{A_H}{A_L}) - \frac{1}{\sigma}ln(\frac{H}{L}) + \frac{(\sigma_A-1)}{\sigma_A}ln(\frac{\alpha_{Hj}}{\alpha_{Lj}}) + \frac{(\sigma_A-1)}{\sigma_A}ln(\frac{B_{Hj}}{B_{Lj}}) - \frac{1}{\sigma_A}[ln(\frac{H_{cj}}{L_{cj}}) - ln(\frac{H}{L})] \tag{2.21}$$

2.5.4 Estimates from Parametric Disaggregated Models

Table 2.4 reports estimates for both the basic disaggregated model and the augmented version. It uses three experience groups, 2-6, 7-21 and 22-36, corresponding to the three age groups for the college graduates used above, where the young and old groups have very different cohort effects. The first three columns report estimates for the basic disaggregated model with alternative specifications for the time trend. They are very similar to Acemoglu and Autor (2011), Table 9, using the same time period. The estimate for σ is 1.6 - 1.7, very similar to the aggregate basic model, and the time effects are similarly large as in the aggregate model. The estimated elasticity of substitution across experience groups, σ_A, is about 3.8, which is almost identical to Acemoglu and Autor (2011). As they note, this is a bit smaller than the estimate of Card and Lemieux (2001) using a large number of age groups and a smaller period of data. While it shows quite high elasticity across experience groups, this estimate still allows a role for differential relative supplies by experience to play a significant role in explaining the age or experience pattern in the wage gap.

The remaining columns in Table 2.4 report the results for the augmented version of the disaggregated model. This shows very different results. Augmenting the disaggregated model has very similar effects to augmenting the basic model on the estimates of σ and SBTC. As in the aggregate version reported in Tables 1 and 2, the estimate of σ is much larger in the augmented version and SBTC is much smaller. The augmented aggregate model in Table 2.2 has a restriction on two of the estimated coefficients relating to σ which is not rejected using the F test reported in Table 2.2. Similarly, equation (2.21) has a testable restriction on two of the estimated coefficients relating to σ_A. The relevant F test is reported in Table 2.4 and the restriction is also not rejected. The estimate of σ_A in the augmented model is much larger. The larger σ_A compared to the standard estimates substantially reduces the role for differential relative supplies by experience to play a significant role in explaining the age or experience pattern in the wage gap.

Table 2.4: Canonical Model with Imperfect Age Substitutability

	Basic Model			Augmented Model		
$ln(H_{cj}/L_{cj}) - ln(H_c/L_c)$	-0.2667	-0.2631	-0.2645	.	.	.
	(6.70)	(6.65)	(6.72)	.	.	.
$ln(H_{cj}//L_{cj} - Ln(H/L)$	.	.	.	-0.1645	-0.1626	-0.1622
	.	.	.	(5.36)	(5.59)	(5.61)
$ln(H_c/L_c)$	-0.6166	-0.5823	-0.6074	.	.	.
	(6.13)	(5.72)	(6.91)	.	.	.
$ln(H/L)$	.	.	.	-0.3537	-0.1434	-0.1208
	.	.	.	(3.64)	(1.34)	(3.92)
$ln(B_{Hj}/B_{Lj})$	.	.	.	0.8582	0.8730	0.8735
	.	.	.	(11.77)	(12.62)	(12.68)
time	0.0320	0.0257	0.0283	0.0199	0.0015	.
	(5.97)	(4.01)	(7.55)	(4.09)	(0.22)	.
$time^2$ x 100	-0.0176	0.0076	.	-0.0153	0.0338	0.0362
	(3.18)	(0.49)	.	(4.07)	(2.63)	(5.58)
$time^3$ x 1000	.	0.0033	-0.0021	.	-0.0060	-0.0062
	.	(1.74)	(3.62)	.	(3.98)	(5.89)
σ_A	3.750	3.801	3.781	6.079	6.150	6.164
σ	1.623	1.717	1.646	2.827	6.974	8.277
F	.	.	.	0.11	0.31	0.31
Prob > F	.	.	.	0.7383	0.5807	0.5784
R^2	0.8513	0.8547	0.8544	0.9220	0.9305	0.9305
N	138	138	138	138	138	138

Notes: Absolute value of t-statistics in parentheses

The under-estimation of σ_A using simple composition adjusted measures parallels the underestimation of σ in the aggregate model using the same type of measures. Carneiro and Lee (2011) do not estimate σ, but they do estimate σ_A and report a much larger estimate of σ_A when they, in effect, take into account the distinction between wages and prices.[28] However, they do not explain why the estimate is higher. In Section 2.3 above (and in the

[28] In fact, they report an even larger σ_A than our estimate in the augmented model.

Appendix) we note that a specific measurement error structure induced by using composition adjustment for both the left-hand-side prices and the right-hand-side quantities will bias the estimate of σ to one. A similar argument applies to σ_A.

2.6 Conclusion

A simple supply-demand model of relative skill prices has been extensively used in the literature to understand the role that supply and demand factors have had on the path of skill premium. This canonical model assumes there are two types of skills (low or high school and high or college-type) which are imperfect substitutes. The key parameters of this model are the elasticity of substitution between college and high school labour, and the rate of growth of college-high school relative demand (skill biased technological change (SBTC)). Assuming linear trend for SBTC, this model yields a very good fit for the evolution of the skill premium over the 1963-1987 period. It implies an elasticity of substitution of around 1.6-1.8 between two labour types, and an important role for SBTC in driving changes in the skill premium over this period.

The performance of the canonical model deteriorates when it is estimated over a longer period. The model exhibits poor out of sample predictions and instability in the estimates of the elasticity of substitution and SBTC. In addition, it implies growth in relative demand for college labour slowed down during the 1990s, which is puzzling given the increase in computer use.

The standard approach to implementing the model in the literature is to use composition adjusted relative wages as a proxy for relative prices, and composition adjusted hours as a proxy for relative supplies (quantities). Composition adjustment of relative wages and hours adjusts for changes in the composition of college vs high school workers due to shifts in education-gender-experience composition of the labour force. This approach imposes a very strong assumption of constant skill levels within these groups over time, and therefore attributes all changes in wages to changes in skill prices alone.

This chapter shows that some of the puzzling findings and poor performance of the canonical model can be explained by mismeasurement of relative skill prices and quantities. Up to two thirds of the change in composition adjusted relative wages is not in fact due to relative price changes, but due to changes in relative average skill levels. Using the price and quantity series from BR, which allow for changes in skill levels, we re-estimate the canonical model to explain the path of skill premium. The results show a much smaller role for SBTC, much higher elasticity of substitution between college and high school labour (around 5.1), and much higher elasticity of substitution between different age groups compared to the standard approach. Decomposition of the college wage premium into components of changes in relative skill prices (net demand and supply effect) and skill levels shows that ignoring the changes in relative average skill levels substantially overestimates the role for SBTC in explaining the increase in college wage premium. The alternative approach also improves the out-of-sample predictions of the model. Furthermore, misestimation of the basic parameters of the canonical model has consequences beyond poor performance, as these parameters, especially the elasticity of substitution, play key roles in the broader literature on human capital.

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Chapter 3

Regional Wages, Skill Prices and College Wage Premia in the U.S.

3.1 Introduction

The dramatic increase in the returns to college during the 1980s triggered a vast literature on explaining the evolution of the college wage premium (e.g. Katz and Murphy (1992), Card and Lemieux (2001), Katz and Autor (1999), and Autor et al. (2008)). The canonical model used in this literature to explain the changing wage structure is a simple model of demand and supply with two types of skills (high school-type and college-type), where their relative skill prices and quantities are determined in equilibrium. The main implications of this model are that rapid secular growth in the demand for higher educated workers (skill-biased technological changes) could be the driving force behind the dramatic increase in educational wage differentials, and that the movements in the college wage premium are strongly related to the rate of growth of the supply of college graduates.

To the extent that the U.S. is made up of distinct local labour markets, it is natural to ask whether this simple framework can also explain movements in relative skill prices at the local level with the same simple demand and supply factors. To date, only a few studies have used the canonical model approach at the local level (Lindley and Machin (2013), Ciccone and Peri (2005)). In the canonical model, differences in relative skill price paths across local markets are determined by local market differences in three components: relative skill supply, relative skill demand (skill biased technological change) and the elasticity of substitution between college and high school labour. While the previous studies allow for differences in relative supply and demand, they do not allow for differences in the elasticity of substitution.

The standard approach to estimating the relative demand equation (regressing relative prices on relative quantities and a time trend) is to use composition-adjusted relative wages as proxies for relative skill prices, and composition-adjusted relative total hours as proxies for relative skill quantities. These composition-adjustments account for changes in the composition of high vs low-skill workers due to shifts in the education, gender and experience composition of the labour force. This methodology is also used at the local level in Lindley and Machin (2013) and Ciccone and Peri (2005).[1]

In theory, payment to human capital is a product of price per unit of skill and quantity of skill supplied. In practice, only total payment to human capital is observed, therefore the price and quantity are not separately identified without strong assumptions. The common practice assumes that skill levels within narrowly defined groups (education, experience and gender) are constant over time. Under this assumption, changes in wages within each group are driven by changes in prices alone. Bowlus and Robinson (2012) relax this assumption, and show that most of the variation in the college wage premium over time in the U.S. is actually explained by variation in college-high school relative skills over time rather than changes in college-high school relative prices.[2] Moreover, the second chapter points

[1]Ciccone and Peri (2005) uses ratios for high school dropout and high school graduate or more instead of high school graduate vs college labour.

[2]Heckman et al. (1998) and Carneiro and Lee (2011) are examples of other studies which also make this

out the problems of nonrobust model parameter estimates of the canonical model (elasticity of substitution between college and high school labour, and rate of skill-biased technological change) and poor out-of-sample predictions after the 1990s (also noted in Acemoglu and Autor (2011)), showing that these problems are mainly due to using composition-adjusted relative wages and hours as proxies for prices and quantities.

In this chapter, I compare the results obtained at the Census-regional level using the standard composition-adjusted implementation with those obtained using the price and quantity series estimated using much weaker assumptions as in the second chapter. Using this approach, I allow for differences in both skill-biased technological change and the elasticity of substitution between college and high school labour across regional markets. Then, I compare implications of the model for skill-biased technological change, the elasticity of substitution, and the path of skill premium based on these two approaches.

The contribution of this chapter is to show that implications of the canonical model are very different when it is implemented using a more general approach (as in the second chapter) compared to the standard approach. Implementation of the canonical model at the regional level using the standard composition adjusted measures yields remarkable differences in the substitutability between college and high school labour across regions with the West having the lowest (1.5) and South having the highest elasticity of substitution (3.7). In addition, the pace of relative demand for college labour was dramatically different across regions with the Midwest having the fastest (average of 2.3% annual growth) and South having the slowest (average of 1.4% annual growth) growth in relative demand, while the West and Northeast showed an average of 2% and 1.7% annual growth in relative demand. Stronger increases in relative demand for college graduates (i.e. faster adoption of skill-biased technologies) in the West and Northeast compared to the South is not surprising given heavier concentration in sectors that require more skilled labour (information tech-

distinction between price and wages.

nology, finance). Similar findings are found in the previous literature (Ciccone and Peri (2005), Lindley and Machin (2013), and Bound and Holzer (2000)) using the composition-adjusted wages and hours.

Implementation of the canonica model at the regional level by relaxing the assumption of constant skills within observable groupings yields the following results: First, in contrast to the standard approach, estimated elasticities of substitution between college and high school labour are more similar across regions, and differences in elasticities are statistically insignificant depending on specification. Second, relative demand movements across regions are more similar compared to the standard approach. The estimated average annual growth rate of relative demand is around 2% for the Northeast, 1.9% for the Midwest, and 1.7% for the Northeast and South. Similarity of relative demand patterns is also supported by Carneiro and Lee (2011) who allow for changes in skill levels over time within groups.[3] This more general approach to implementing the canonical model suggests a reduced role for differences in relative demand patterns and elasticities across regions in explaining differences in relative skill price movements over time across regions.

The rest of the chapter is organized as follows. Section 3.2 explains the data used in this chapter. Section 3.3 explains the canonical model and estimates this model at the regional level using conventional measures for college-high school ratios of skill prices and skill stocks. Section 3.4.1 describes the model where prices and wages are distinguished. Section 3.4.2 estimates regional price series, and describes the estimated price series. Section 3.4.3 explains how human capital stocks are predicted and presents the predicted human capital stock ratios of college and high school labour. Section 3.4.4 re-estimates the canon-

[3] They use an entirely different method to estimate skill quantity changes. They identify skill level (quality) changes by comparing wages of workers in the same labour market, but were born in different regions, which have different college enrolment rates, and presumably different average quality of workers with any college college education. They find that the average annual growth rate in relative demand for college labour is around 1.7% for the Northeast and West, and 1.6% for the Midwest and South over the period 1960-2000 period. They use Census data, while this chapter uses the CPS.

ical model using price series and human capital stocks found in Sections 3.4.2 and 3.4.3, and then presents the parameter estimates of the canonical model at the regional level, comparing findings on differences in changes in relative demand for college labour and elasticities across regions with results from the standard approach. Section 3.5 concludes.

3.2 Data

This chapter uses the March Current Population Survey from survey years 1964 to 2009. The corresponding earnings years are 1963-2008. A full-time full-year wage sample is used in the construction of price series. This wage sample includes all individuals from the sample who usually worked at least 35 hours a week for at least 40 weeks in the previous year.

There are inconsistencies in some of the variables used to construct hourly wages. Since usual weekly hours for the previous year are only available since the survey year 1976, I use hours worked during the survey week to measure average hours worked in the previous year. Usual weekly hours for those who did not work during the survey week, but worked last year, are imputed by using using predicted hours from a regression of "hours last week" on age, years of schooling and a female dummy variable for each year based on the sample of those employed in the survey year. Moreover, data on the number of weeks worked is bracketed before the survey year 1976. UNICON imputes number of weeks worked for the earlier surveys by using the means of weeks worked reported for several survey years after 1976 for each bracket used for weeks worked before 1976. These means of weeks worked for each bracket are then assigned to the corresponding weeks brackets in the earlier survey years 1964-1975. Due to these inconsistencies between the 1964-1975 and 1976-2009 data sets, I estimate the price series separately for these two time periods and normalize the prices to 1 in years 1975 (earnings year 1974) and 1976 (earnings year 1975).

The Education variable in the CPS was redefined in 1992. Before 1992, I define high school dropouts (HSD) as those with fewer than twelve years of completed schooling, high school graduates (HSG) as those with twelve years of completed schooling, those who attended some years of college (SMC) as those with schooling beyond twelve years and less than sixteen completed years, college graduates and post graduates (CLGp) as those who completed at least sixteen years of schooling. After 1992, high school dropouts are defined as those with fewer than twelve years of completed schooling, high school graduates as those with either twelve completed years of schooling and/or a high school diploma or a G.E.D., some college as those attending some college or holding an associates degree, and college graduates and post graduates as those with a B.A. or degrees higher than B.A.

3.3 Canonical Model: Standard Implementation at the Regional Level

3.3.1 Model

Most studies that analyse changes in the wage structure use a model of demand and supply of skills. The college-high school skill price premium is determined by the college-high school relative supply and relative demand for skills. Katz and Murphy (1992) modelled the effects of relative demand and supply on the college-high school skill price premium in a perfectly competitive environment with two types of labour (college and high school equivalents) which are imperfectly substitutable and where the aggregate production is assumed to be a constant elasticity of substitution (CES) production function. The aggregate production function is given by

$$Y_t = \left[\theta_t (H_t^C)^\rho + (1-\theta_t)(H_t^{HS})^\rho\right]^{\frac{1}{\rho}}, \tag{3.1}$$

where H_t^e denotes the total supply of skills by labour type e. The elasticity of substitution between college and high school labour is given by $\sigma = 1/(1-\rho)$. The competitive labour market assumption implies that unit prices of skill supplied by high school and college labour are given by

$$p_t^e = \frac{\partial F(H_t^C, H_t^{HS})}{\partial H_t^e} \quad \text{for } e = C, HS.$$

More precisely,

$$\begin{aligned} p_t^e \quad & = \theta_t \left(\frac{Y_t}{H_t^e}\right)^{\rho-1} && \text{if } e = C \\ & = (1-\theta_t)\left(\frac{Y_t}{H_t^e}\right)^{\rho-1} && \text{if } e = HS. \end{aligned} \tag{3.2}$$

Using Equation (3.2) and taking logarithms of the ratio of unit wages for low and high skilled labour gives

$$\ln p_t^C - \ln p_t^{HS} = \ln\left(\frac{\theta_t}{1-\theta_t}\right) + (\rho - 1)\left(\ln H_t^C - \ln H_t^{HS}\right). \tag{3.3}$$

Changes in the first term represent changes in relative demand for college labour. The standard assumption is that there is skill-biased technological change that follows a linear trend: $\ln\left(\frac{\theta_t}{1-\theta_t}\right) = \alpha_0 + \alpha_1 t$. Under this assumption, Equation (3.3) becomes:

$$\ln p_t^C - \ln p_t^{HS} = \alpha_0 + \alpha_1 t + (\rho - 1)\left(\ln H_t^C - \ln H_t^{HS}\right). \tag{3.4}$$

Estimates of α_1 describe the extent of technological change in favor of skilled labour, while estimates of elasticity of substitution between college and high school labour can be determined from estimates of $\rho - 1$ ($\hat{\sigma} = \frac{1}{\hat{\rho}-1}$).

3.3.2 The Standard Approach to Implementation of the Canonical Model

In this section, I re-estimate the canonical model at the regional level allowing all parameters of the model to differ across regions. Equation (3.4) becomes

$$\ln p_{rt}^{C} - \ln p_{rt}^{HS} = \alpha_{0r} + \alpha_{1r}t + (\rho_r - 1)\left(\ln H_{rt}^{C} - \ln H_{rt}^{HS}\right). \tag{3.5}$$

Composition-Adjusted Wages and Hours

The standard approach to estimating Equation (3.4) is to use the ratio of composition adjusted total hours supplied by each labour type to proxy for relative skill supply, $\frac{H_t^C}{H_t^{HS}}$, and to use the ratio of composition adjusted wages for each labour type to proxy for the relative skill prices, $\frac{p_t^C}{p_t^{HS}}$.[4]

To compute the composition-adjusted wages, I sort the data into gender-experience-education groups for each region. There are five experience (0-9, 10-19, 20-29, 30-39) and five education categories (high school dropout, high school graduate, some college, college graduate, college-plus). I regress log weekly wages in each year separately by region and gender on indicators for four education categories, a quartic polynomial in experience, race dummies, region dummies, interactions of the experience polynomials with high school graduate, some college, and college plus dummies. The composition-adjusted log wage for each gender-experience-education group is given by the predicted mean log weekly wages from these regressions for each region. The composition-adjusted log wage for high school labour is computed as the weighted mean of these gender-experience-specific high school graduate composition-adjusted log wages using a fixed set of weights equal to the average share of total hours worked by each group over 1963-2008 period.

[4] Katz and Murphy (1992), Autor et al. (2008), Card and Lemieux (2001), Katz and Autor (1999), Lindley and Machin (2013), Ciccone and Peri (2005).

The composition-adjusted log wage for college labour is computed as the weighted mean of gender-experience-specific composition-adjusted log wages of college graduates and college-plus using the fixed set of labour supply weights. The dependent variable for Equation (3.5) is then computed as the difference between the two composition-adjusted log wage measures in each year and region.

To compute the composition-adjusted relative supply of college labour, I compute the total hours worked by all employed workers with 0 to 39 years of potential experience in gender-experience-education cells for each region, where experience categories are single-year categories. I compute mean weekly wages for each gender-experience-education cell in each year, and divide these mean wages by the wages of high school graduate males with ten years of experience for all years. I then compute an efficiency unit measure for each gender-experience-education cell as the average of the normalized wage in that cell over the 1963-2008 period. There are two types of labour: high school-equivalent and college-equivalent labour. The college-equivalent labour supply is computed as the total efficiency units of labour supplied by college or college-plus and half of the efficiency units of labour supplied by some college. The high school-equivalent labour supply is the total efficiency units of labour supplied by high school graduates or high school dropouts plus half of the efficiency units supplied by some college.[5] The college/high school log relative supply index is given by the log ratio of college-equivalent to high school-equivalent labour supply in each year and region.

The implicit assumption in this approach to computing relative prices and quantities is that skill levels within each education-experience-gender group are constant over time. Therefore, this approach would break down if there are changes in skill levels for cohorts

[5]This type of allocation of some college group to high school-equivalent and college-equivalent labour groups is also used by Katz and Murphy (1992), Card and Lemieux (2001), Acemoglu and Autor (2011), and Lindley and Machin (2013).

over time.[6]

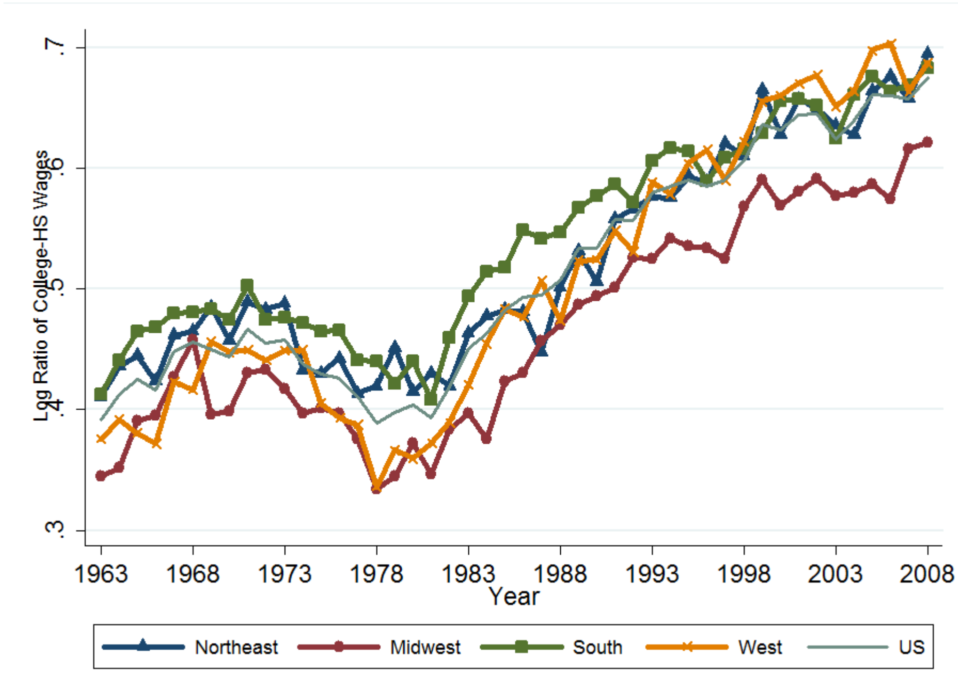
Figure 3.1 shows the log difference of college graduate and high school graduate composition-adjusted average wages, the standard measure for college-high school relative skill price in the literature, for Census regions; Northeast, Midwest, South, and West. There are considerable differences in the college wage premia across regions at a point in time, as well as differences in the evolution of college wage premium across regions depending on the time period. The 1960s and 1970s are characterized by a declining national average for the college wage premium, while the 1980s is characterized by much more dramatic increases in college wage premium in the South and West compared to Northeast and Midwest. In the last decade, college wage premia seem to have converged across regions except for the Midwest. Similar findings on wage inequality are also given by Topel (1994), Bound and Holzer (2000), Bernard and Jensen (2000), and Borjas and Ramey (1995).

Figure 3.2 shows the ratio of composition-adjusted hours for college and high school labour, the standard measure of relative skill supply of college-high school labour for Census regions. Relative supplies of college labour increase steadily in all regions and at very similar rates across regions until the 1980s. There seems to be an overall decrease in the rate of growth of relative supply in early 1980s in all regions, but the growth of relative supply slows down considerably in the West compared to other regions in early 1980s, and the other regions seem to follow each other rather closely. Similar supply evidence is provided by other studies in the literature. Topel (1994) finds regional variations in relative supply changes and that the West is the region with the slowest growth in high-low skilled relative supply between 1972 and 1990. Lindley and Machin (2013) do not provide results for supply changes for all states, but they report that Massachusetts saw the greatest, and New Mexico and Wyoming saw the smallest increase in relative supply of college labour.[7]

[6]Evidence on changes in skill levels over time for cohorts are given by Heckman et al. (1998), Carneiro and Lee (2011), and Bowlus and Robinson (2012).

[7]Ciccone and Peri (2005) use relative supply of high school dropout and high school graduate or more at

Figure 3.1: College-High School Wage Gap By Region



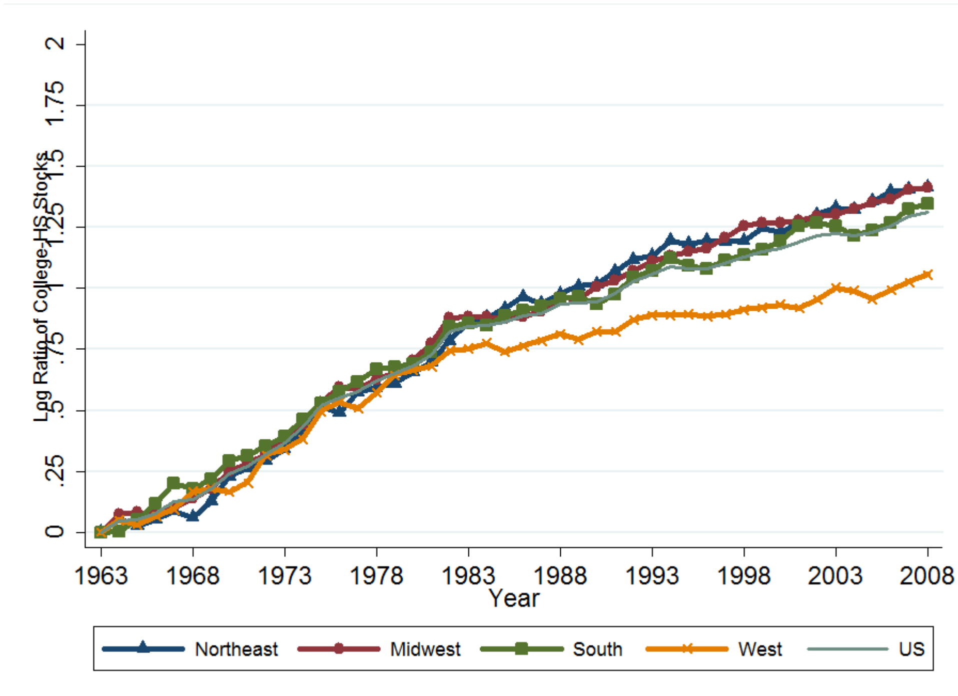
Estimation Results from Standard Approach

As seen in Figures 3.1 and 3.2, movements in college wage premia are not necessarily accompanied by movements in the opposite direction in relative supply of college labour. For example, faster increases in college wage premium in the Northeast compared to Midwest in Figure 3.1 are not accompanied by slower rates of increase in relative supply of college labour in this region. This suggests that there may be differences in relative demand changes, and elasticities of substitution between college and high school type labour across regions.

Table 3.1 shows the results from estimation of Equation (3.5) using the composition adjusted wage ratios and labour supply ratios. The first column shows results for the 1963-2008 period using a linear trend specification for relative demand for college labour. The elasticity and trend estimates are quite precise. We fail to reject the equality of elasticities

the state level, and do not provide detailed results on supply changes at the state level.

Figure 3.2: Log College-High School Composition Adjusted Relative Supplies, 1963-2008



Note: Normalized at 0 in 1963.

of substitution across regions. The second and third columns report estimates from specifications using quadratic and cubic trend polynomials. Note that estimates for elasticities of substitution for the West and South are very sensitive to inclusion of higher order trend polynomials. The preferred specification here is the cubic trend specification for all regions, since the coefficients for cubic trend terms are all statistically significant at the 10% level.

In the third column of Table 3.1, the West has the lowest elasticity of substitution ($\frac{1}{0.653} = 1.5$) and the South has the highest ($\frac{1}{0.273} = 3.7$). Although, it is common practice in the literature to assume that elasticities are equal across local markets, this assumption is rejected here.[8]

[8]Lindley and Machin (2013), Ciccone and Peri (2005), and Carneiro and Lee (2011) assume the same elasticities across local markets.

Table 3.1: Estimates of the Regional Canonical Model Using Composition Adjusted Wage Ratios and Supply Ratios, 1963-2008

	(1)	(2)	(3)
$\ln(H^{C}_{rt}/H^{HS}_{rt})$ X Northeast	-0.340	-0.219	-0.353
	[0.051]**	[0.100]*	[0.099]**
$\ln(H^{C}_{rt}/H^{HS}_{rt})$ X Midwest	-0.377	-0.509	-0.540
	[0.055]**	[0.116]**	[0.106]**
$\ln(H^{C}_{rt}/H^{HS}_{rt})$ X South	-0.247	-0.350	-0.273
	[0.051]**	[0.127]**	[0.121]*
$\ln(H^{C}_{rt}/H^{HS}_{rt})$ X West	-0.398	-0.700	-0.653
	[0.043]**	[0.097]**	[0.093]**
t X Northeast	0.017	0.010	0.006
	[0.002]**	[0.006]+	[0.005]
t X Midwest	0.018	0.026	0.017
	[0.002]**	[0.006]**	[0.006]**
t X South	0.013	0.019	0.008
	[0.002]**	[0.007]**	[0.008]
t X West	0.017	0.034	0.026
	[0.001]**	[0.005]**	[0.006]**
t^2 X Northeast		0.007	0.058
		[0.005]	[0.015]**
t^2 X Midwest		-0.007	0.043
		[0.006]	[0.015]**
t^2 X South		-0.006	0.036
		[0.007]	[0.018]*
t^2 X West		-0.021	0.009
		[0.006]**	[0.018]
t^3 X Northeast			-0.008
			[0.002]**
t^3 X Midwest			-0.007
			[0.002]**
t^3 X South			-0.005
			[0.002]*
t^3 X West			-0.004
			[0.002]+
N	184	184	184
R^2	0.997	0.997	0.998
Test on Equivalence of Elasticities			
F-stat	1.875	4.306	2.792
p-value	(0.136)	(0.006)	(0.042)

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$

State or MSA-level labour markets may be fairly specialized (e.g. abundance of oil or other natural resources) in their production. Therefore, one could expect to see different kinds of production technologies across finer levels of labour markets. On the other hand, Census regions are fairly large labour markets which are aggregates of different states. Thus, a smaller degree of specialization is likely at the regional level. Therefore, differences in production technologies across regions suggested by very different estimates for elasticities of substitution between college and high school labour are somewhat puzzling.

Using estimates in the third column of Table 3.1, I compute the implied relative demand series as:

$$\ln D_{rt}^{C} - \ln D_{rt}^{HS} = \ln p_{rt}^{C} - \ln p_{rt}^{HS} - (\hat{\rho}_r - 1)\left(\ln H_{rt}^{C} - \ln H_{rt}^{HS}\right). \tag{3.6}$$

Figure 3.3: Predicted Relative Demand for College Labour from the Estimation Using Composition-Adjusted C-HS Relative Wages and Labour Supply

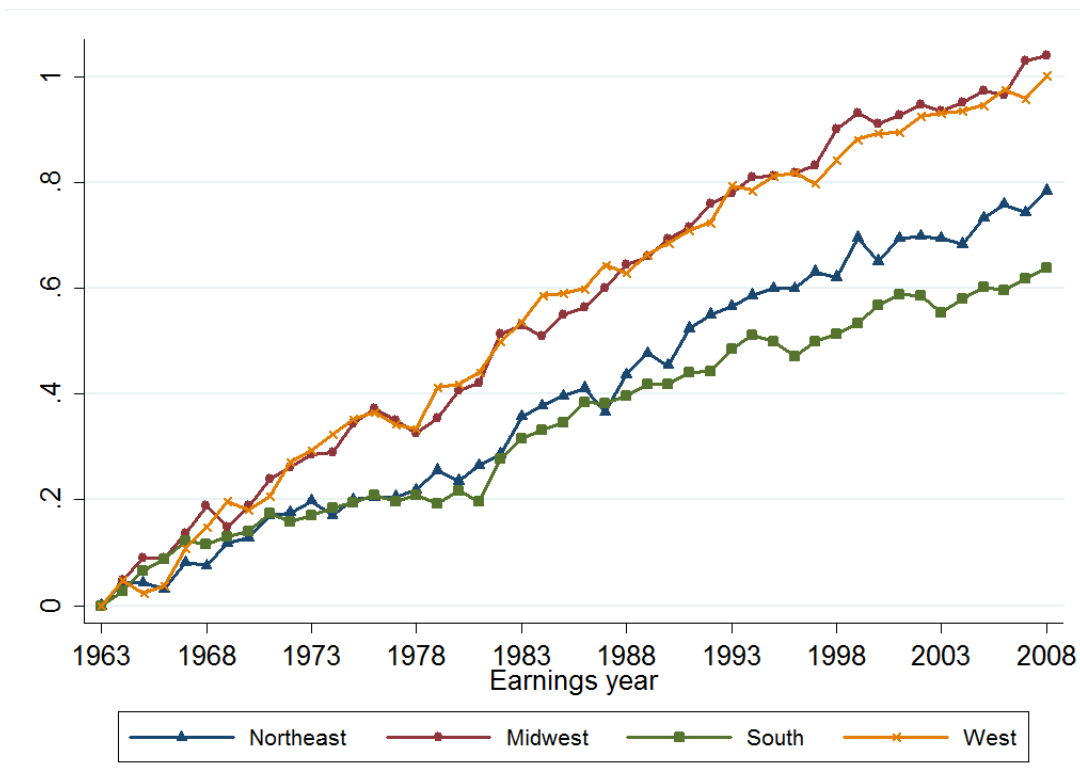


Figure 3.3 shows the implied relative demand for college labour for each region. Midwest and West seem to have very similar patterns for relative demand for college labour throughout 1963-2008 period, while South and Northeast exhibit much slower rates of growth in relative demand compared to Midwest and West. The estimated average annual growth rate in relative demand for college labour is 2.3% for the Midwest, 2.2% for the West, 1.7% for the Northeast, and 1.4% for the South. The West and Northeast having faster increases in relative demand compared to the South is intuitive, as they are more concentrated in sectors that require high skilled labour (information technology, finance). The fast increase in relative demand in the Midwest during the 1980s and after could be due to deterioration of manufacturing sector as mentioned by Bound and Holzer (2000).

The results are qualitatively similar to those found in Lindley and Machin (2013), Ciccone and Peri (2005), and Bound and Holzer (2000). Lindley and Machin (2013) and Ciccone and Peri (2005) use the canonical framework to understand changes in local relative prices. Ciccone and Peri (2005) use state level data from U.S. Census for 1950-1990 period to estimate long-run elasticity of substitution between more and less skilled workers. They find that many Western states experienced large increases relative demand for more educated workers (several with around 8% average annual growth), and several Southern states had rates lower than 5% per year.[9] They point out that these differences in relative demand changes could be due to different patterns of sectoral specialization, but they do not investigate this any further. Lindley and Machin (2013) report that Massachusetts and New York in the Northeast, and Illinois in the Midwest have high rates of growth in relative demand for college labour, while shifts in relative demand are much lower in West Virginia in the South.[10] They find that changes in unionization rates and changes in R&D expenditures are negatively and positively correlated with changes in relative demand. Bound and

[9]The rates of increases are estimated to be significantly larger than what is found here, because the authors categorize less skilled as high school dropouts and more skilled as those with a high school degree or above.

[10]They do not report the number for growth rates of relative demand for college labour.

Holzer (2000) find that relative demand for college labour grew faster in industrial areas in Midwest compared to MSAs in Northeast, like Boston and New York, which is in line with findings here.[11]

Qualitative implications of the model change when a common elasticity of substitution across regions is assumed. In the case with common elasticity, the difference in relative demand shifts across regions are not as pronounced as implied by model specification which allows for differences in elasticities. Average annual growth rate of relative demand for college labour is estimated as 2.1% for Northeast and Midwest, 2% for South, and 1.8% for West. Therefore, allowing for differences in elasticities at the regional level considerably affects relative demand implications of the canonical model.

Given that Census regions are relatively aggregated labour markets, it is worth re-examining the analysis here which suggests very large differences in elasticities across regions. The differences in growth rates of relative demand for college labour are also quite significant, which is contradicted by Carneiro and Lee (2011) who also allow for changes in skill levels within groups over time, find very similar relative demand patterns for regions over the 1960-2000 period, unlike previous studies at the local level using composition-adjusted wages and hours.[12]

One problem with the estimated model here could be that the college-high school relative prices and skill stocks may be mismeasured if there is any change in relative skill levels of college and high school workers within defined education-experience-gender cells. In fact, Card and Lemieux (2001) and Acemoglu and Autor (2011), who assume constant skills within observable groupings, show that changes in college-high school relative wages

[11]Bound and Holzer (2000) do not implement the canonical framework discussed here. They focus on directly estimating the effect of local demand shifts on wages of college and high school or less labour. They create an index for demand based on national growth of hours worked in industries, weighted by MSA-specific shares of hours worked in those industries. They use this index to instrument overall local employment growth, and report changes in predicted relative demand for college labour.

[12]Bound and Holzer (2000), Ciccone and Peri (2005), and Lindley and Machin (2013).

over time for different experience groups are not the same.

Payment to human capital is a product of price per unit of skill and quantity of skill supplied. The standard approach arbitrarily separates skills from prices by assuming all workers within the same education-experience-gender group have the same skill level over time, so all wage movements are assumed to be driven entirely by changes in skill prices. Evidence at the national level from the second chapter suggests that some of the puzzling results found in this section could be due to violation of key assumption that skills are constant over time within observable groupings.

In the next section, I estimate regional skill prices and show that the directions of movements in regional college-high school relative prices and composition adjusted wages are not the same. I re-estimate the canonical model using these regional skill prices and supplies, and argue that some of the puzzling results mentioned above obtained from the standard approach may be due to mismeasurement of prices and quantities. Before presenting the results on regional skill prices and estimates of the canonical model, I briefly describe the model used and the distinction between wages and prices in more detail in the next subsection.

3.4 Implementation at the Regional Level: Relaxing the Assumption of Constant Skills within Groups

3.4.1 Wages, Prices and Human Capital

In the presence of human capital investment, the link between wages and prices is broken. Wages reflect the product of the price of a unit of human capital or "skill" and the quantity of human capital supplied: $w_{it} = p_t E_{it}$, where w_{it} denotes the wage of individual i in period t, E_{it} denotes the quantity of human capital supplied (number of efficiency units) or "utilized" skill by individual i in period t, and p_t denotes the price paid per unit of human capital in the labour market. In a Becker (1964) or Ben-Porath (1967) framework, utilized skill is given by $E_{it} = h_{it}(1 - n_{it})$, where h_{it} denotes the skill level of individual i, and n_{it} denotes the fraction of time at work allocated to producing skills. In practice, only the total payment to human capital is observed, therefore the price and utilized skill cannot be separately identified. Implicit identifying assumptions made in the literature are either that the price of human capital is constant over time or that the quantity of human capital (conditional on some observable characteristics such as education, experience and gender) is constant over time. Studies which assume constant human capital levels over time within education-experience-gender groups include Katz and Murphy (1992), Card and Lemieux (2001) and Autor et al. (2008).[13] Some of the few exceptions which allow for changes in skill levels over time within groups are Heckman et al. (1998), Huggett et al. (2011), Carneiro and Lee (2011), and Bowlus and Robinson (2012).

The human capital model used here is based on the extended Ben-Porath model used in Heckman et al. (1998) and Kuruscu (2006). In Heckman et al. (1998), the Ben-Porath model is modified to allow for heterogeneity in human capital levels or skills. Skill groups are associated with different education groups and each skill group is subject to different skill prices. Workers of all ages (within an education group) are assumed to have the same type of human capital, and therefore, they are subject to the same price. Heckman et al. (1998) use the implication of the Ben-Porath model for constant utilized skill levels towards the end of working life to develop a strategy for the identification of price changes. At older ages, when there is no longer any skill investment ($n_{it} = 0$), changes in wages are generated only by changes in prices. Therefore, wage changes for older workers can be used to identify price changes. The implicit assumption here is perfect substitutability

[13] Some of the studies which make the assumption of constant prices over time include Ben-Porath (1967), Mincer (1974) and Kuruscu (2006).

between young and old workers.[14] In particular, for individuals who are in the "flat spot" region of their life-cycle efficiency units profile:

$$Mean\left[\ln E_{i,a,t}\right] = Mean\left[\ln E_{i,a+1,t+1}\right] \Rightarrow Mean\left[\ln w_{i,a+1,t+1}\right] - Mean\left[\ln w_{i,a,t}\right] = \ln p_{t+1} - \ln p_t \tag{3.7}$$

The choice of the flat spot age intervals is important. Heckman et al. (1998) note that there could be differences in endowments, ability and human capital production function across different cohorts, which could make it difficult to identify the appropriate age interval during which skill levels are constant, however they ignore these effects. Bowlus and Robinson (2012) build on Heckman et al. (1998) by allowing for cohort effects in the form of selection effects and technological improvements in human capital production functions. They use cross section data for college graduates to sign the bias that is introduced by cohort effects, and identify the appropriate flat spot region in the age-utilized skill profile as the region where the bias from cohort effects is removed.[15]

Another paper which uses the flat spot approach is Huggett et al. (2011). They study the sources of variation in lifetime earnings, wealth and utility in the U.S. using a model where human capital is subject to idiosyncratic shocks in each time period. They estimate this shock process using changes in wage moments for older males.

Both Bowlus and Robinson (2012) and Heckman et al. (1998) find that accounting for the distinction between prices and wages is important for understanding the evolution of wages, since prices and wages can move differently. Heckman et al. (1998) simulate the effects of a skill-biased technological change and find that wages and prices move in opposite directions in the earlier stages of the transition while the increase in the college-high

[14] This assumption is relaxed in Card and Lemieux (2001). They find strong substitutability by age. However, they do not account for the fact that human capital investment levels may vary by age and over time. They implicitly assume that n_{it} is fixed.

[15] For a more detailed explanation on the framework for choosing the flat spots, see Bowlus and Robinson (2012).

school wage differential is greater than the increase in relative skill prices in later stages due to rational investment behaviour.[16] In the light of the evidence given by Heckman et al. (1998), Bowlus and Robinson (2012), and the second chapter, it is important that we make a careful distinction between wages and prices. Failure to account for changes in human capital levels over time (even within education-experience-gender groups) when estimating the canonical model may produce misleading results. The next section estimates price series at the regional level and describes the movements in prices and relative prices of college-high school labour across different regions.

3.4.2 Regional Skill Prices

Estimation

I estimate the regional price series for four different human capital types defined by education categories: college graduates, some college, high school graduates, and high school dropouts. I use the flat spot approach to estimate these prices and use the methodology in Bowlus and Robinson (2012) to select the flat spots for each region. This suggests using the flat spot ages 50-59 for college graduates, 48-57 for those with some college education, 46-55 for high school graduates, and 44-53 for high school dropouts for all regions. The methodology used for estimating prices requires working with wages of older workers which leaves very small sample sizes at local levels finer than Census regions, i.e. state or MSA level. Thus, local markets are defined by Census regions rather than states or MSAs.

Equation (3.7) suggests constructing price series from mean log wage differences for those who are in the flat spot age range. I use medians instead of means to avoid problems due to time varying top-coding of income and allocated values in earnings. Since the data used are repeated cross-sections, I do not observe the same individuals for two years in a

[16]Heckman et al. (1998) pages 29-33.

row, but I can follow cohorts from one year to the next. I compute age-specific median wages for each education group and year. Then, within an education category, for example for the college graduates, I compute the average of log median wages for 50-58 year old workers in year $t - 1$ and the average for 51-59 year old workers in year t, and take the difference of the two for each t. The price in year t is then estimated as the cumulative sum of these differences up to year t relative to a baseline year.

Estimated Series

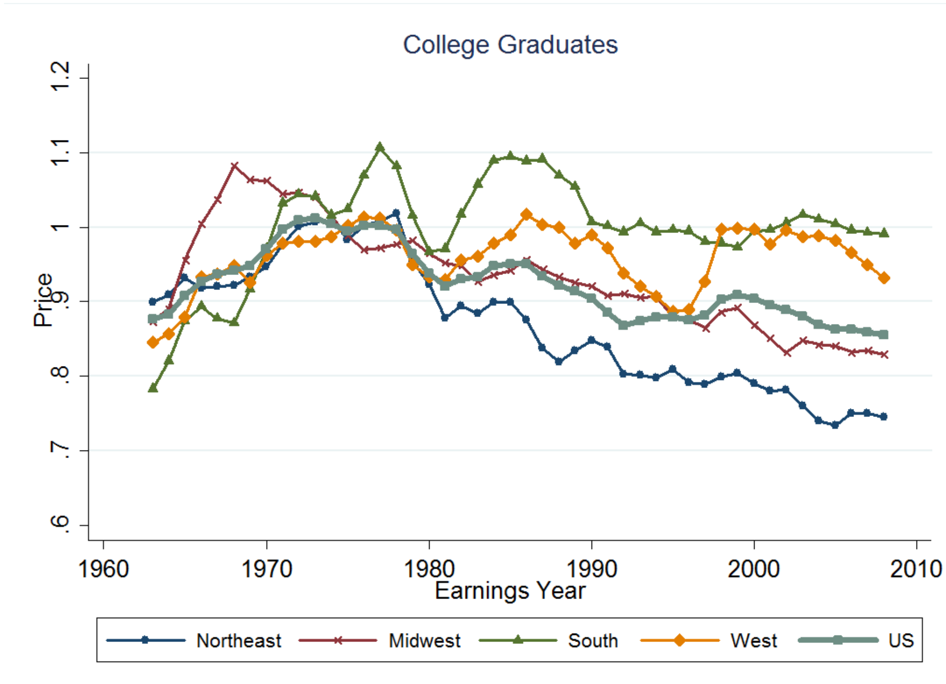
Figure 3.4 plots the estimated price series for each Census region and the U.S. for 1963-2008.[17] National prices (inferred from looking at the entire country) for all education groups are increasing during the 1960s and 1970s and follow a downward trend after the 1970s. College prices in the Northeast and Midwest follow the national trend very closely, whereas college prices in the South and West regions do not. During the 1960s and 1970s, the college price increased faster in the South compared to other regions, and it was more or less stable from then on. In the West, the college price saw a sharper decline during the 1990s compared to other regions before it recovered in the 2000s.

The overall patterns for high school prices are very similar across regions. The only exception is the West region during the late 1980s, where the high school price saw a much sharper decline compared to other regions. Similarly, for high school dropout and some college prices, the overall patterns look similar across the regions with some exceptions: During the late 1980s, the dropout price saw the largest decline in the Midwest, while it was more or less stable in the other regions during that time. The price for some college saw a larger decline in the Midwest during the late 1980s and after compared to other regions, which followed the national trend closely.

[17]The prices are normalized to one in 1974 and 1975 for each education group in all regions as explained in Section 3.2.

Figure 3.4: Price Series By Education Group and Region: 1963-2008

(a)



(b)

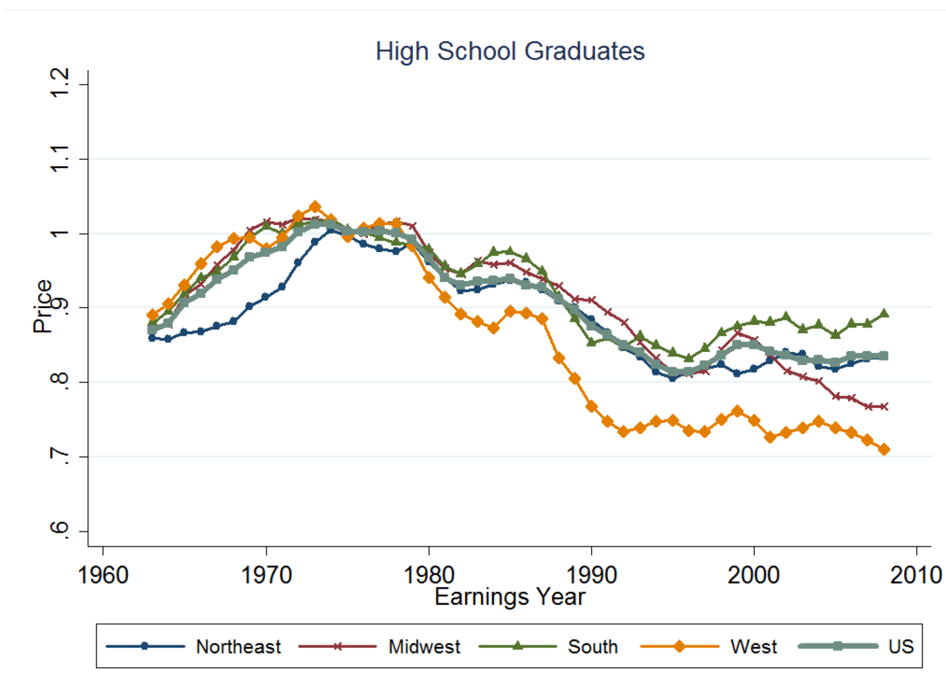
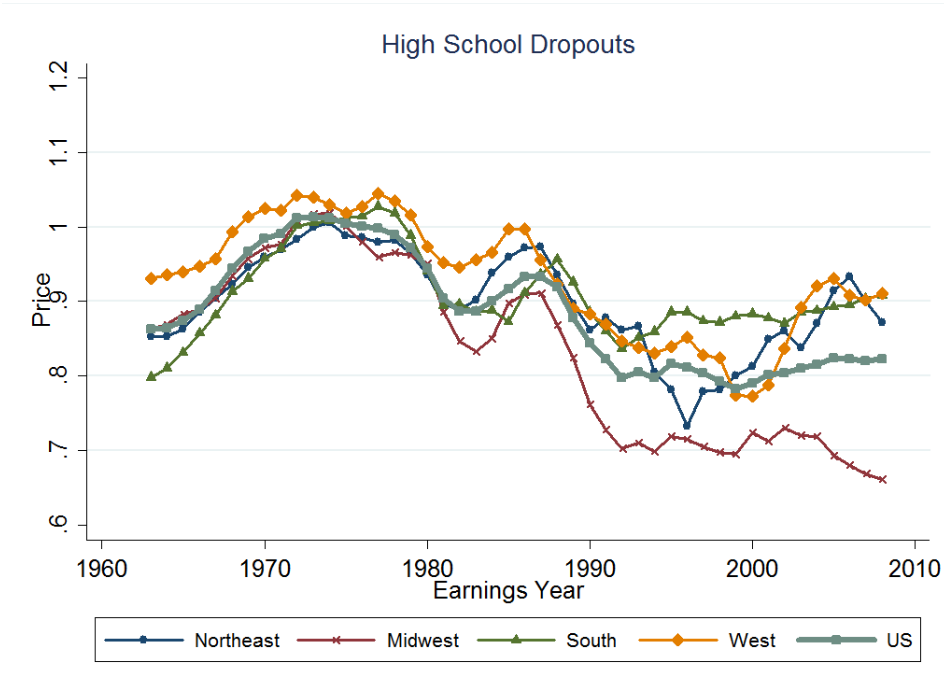


Figure 3.4: *continued*

(c)



(d)

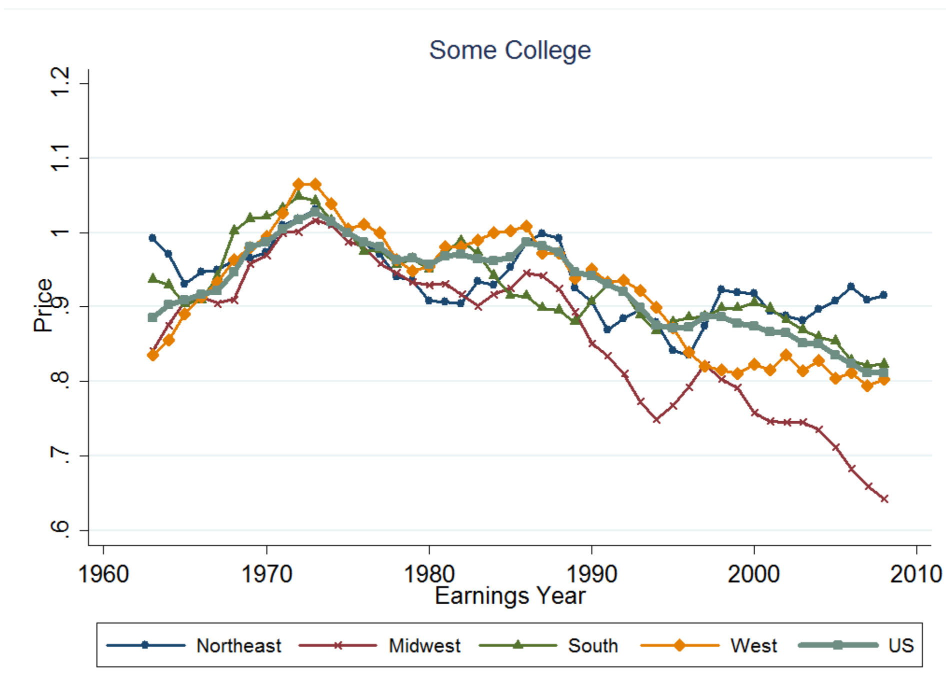
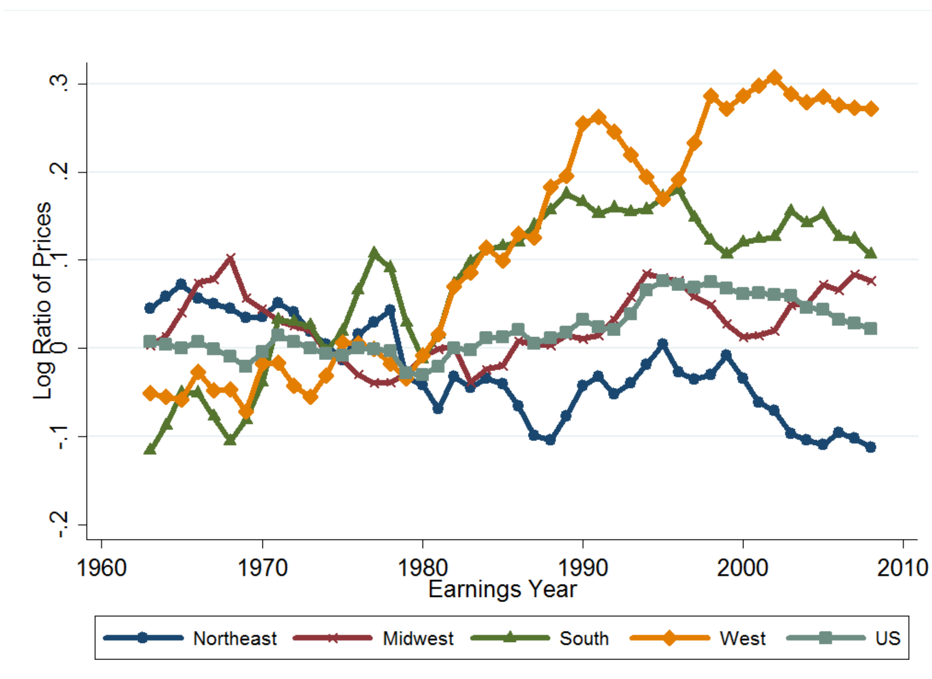


Figure 3.5 shows that relative price movements differ significantly across regions, while Figure 3.1 shows more similar patterns for college-high school relative wages across regions. Therefore, the composition-adjusted college wage premium masks important trend differences in skill prices, and therefore in skill quantities, over time across the regions.[18] Relative prices decreased between the 1960s and 1980s in the Midwest, and decreased between the 1960s and 1990s in the Northeast. This implies that the increases in college wage premia during these periods in these regions were mostly due to increases in the relative quality of college and high school labour. This can be seen in Figure 3.6, which shows the log ratio of college-high school average skill quantities.[19] Relative prices in the South are more or less stable since the 1990s while college wage premium increased steadily in this region. Figure 3.6 shows that increases in college wage premium in the South since

Figure 3.5: Log Ratio of College-High School Prices: 1963-2008



[18]Carneiro and Lee (2011) also finds evidence for differences in wage and price movements.

[19]Log ratio of average skill quantities are calculated as differences between log average wage ratios and log price ratios

the 1990s were mostly driven by increases in college-high school average skill quantity ratios. In contrast, increases in college wage premia in the West seem to be driven mostly by increases in relative prices, especially in the 1980s. Southern relative prices increase at a faster rate during the 1970s compared to other regions, which shows decreasing ratios for average skill quantities over this period.[20] This is also true for the West, which exhibits decreasing relative skill quantities during the 1970s. These decreases in average relative skill quantities are mainly driven by increases in average skill levels of high school graduates during this period.

3.4.3 Regional Stocks of Human Capital

One of the components of the canonical model is the ratio of human capital stocks of college and high school type labour. The regional stocks of human capital can be computed using the estimates for regional skill prices from Section 3.4.2. As shown in Section 3.4.1, the total payment to an individual in region r who belongs to education category e is given by $w^e_{irt} = p^e_{rt}E^e_{irt}$, where the p^e_{rt} and E^e_{irt} are the unit price for skill and efficiency units of human capital supplied by the individual. This implies:

$$WB^e_{rt} = p^e_{rt}H^e_{rt}, \tag{3.8}$$

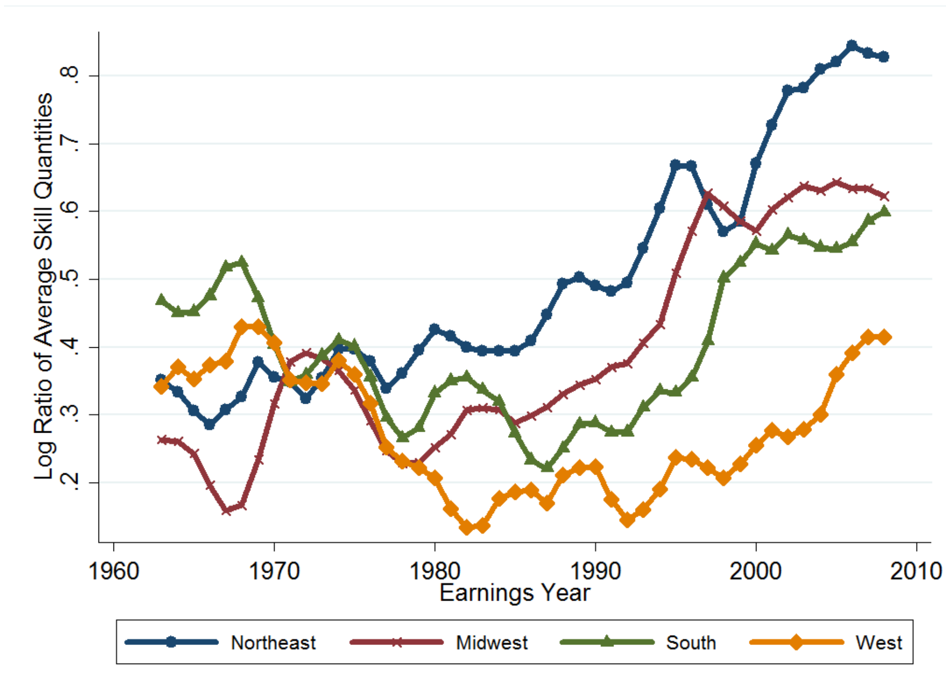
where WB^e_{rt} is the total expenditure or wage bill, and H^e_{rt} is the total efficiency units or skill stock of education group e in region r. The regional skill stocks are estimated using the

[20]Relative price estimates obtained by using flat spot age groups 49-58 and 51-59 also imply fast decreases in relative average skill quantities for the South and West with South having faster decreases.

skill price estimates and total annual wages and salaries data from the CPS:[21]

$$\hat{H}^e_{rt} = \frac{\sum_{i=1}^{N^e_r} w^e_{irt}}{\hat{p}^e_{rt}} \tag{3.9}$$

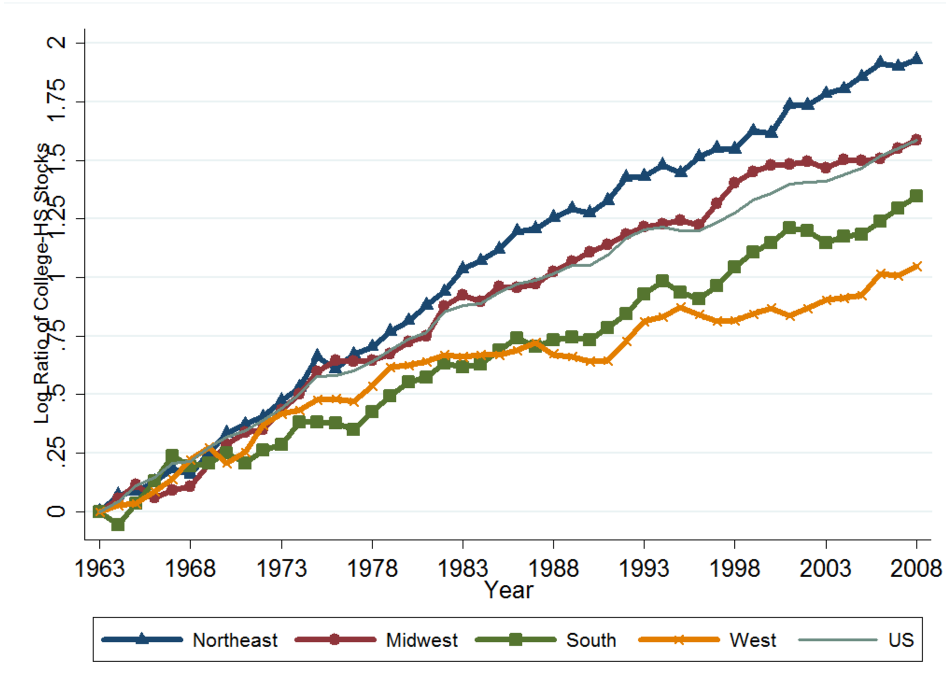
Figure 3.6: Log Ratio of Average College-High School Skill Quantities: 1963-2008



These education and region-specific human capital stocks are aggregated into two categories of human capital stock: college and high school equivalents. Figure 3.7 shows the log ratio of college and high school-equivalent skill stocks for each region. There are remarkable differences in the movements of relative stocks across regions. The West and South exhibit slower growth compared to the Northeast and Midwest most of the time throughout 1963-2008. This figure also highlights the stark difference between college-high school relative skill supply measures computed using prices and quantity series estimated without the assumption of constant skill levels within groups, and those that use

[21]The sample used to calculate local human capital stocks includes individuals with positive wages and salaries and excludes those who are self-employed.

Figure 3.7: Log College-High School Relative Skill Stocks, 1963-2008



Note: Normalized at 0 in 1963. Skill stocks are estimated by dividing wage bills by estimated price series

composition-adjusted hours as in the standard approach (Figure 3.2).

3.4.4 Re-Estimating the Canonical Model Using the Alternative Prices and Quantities

Section 3.4.2 showed that price series show remarkable differences across regions. These differences can be driven by differences in shifts in relative demand and/or supply for college labour, or differences in elasticities of substitution between college and high school labour. In this section, I re-estimate the canonical model using the estimates for regional relative college-high school skill prices and human capital stocks found in Sections 3.4.2 and 3.4.3. As in Section 3.3.2, I estimate Equation 3.5 allowing all the parameters to differ by region.

Table 3.2: Estimates of the Canonical Model Using Prices and Quantities: 1963-2008

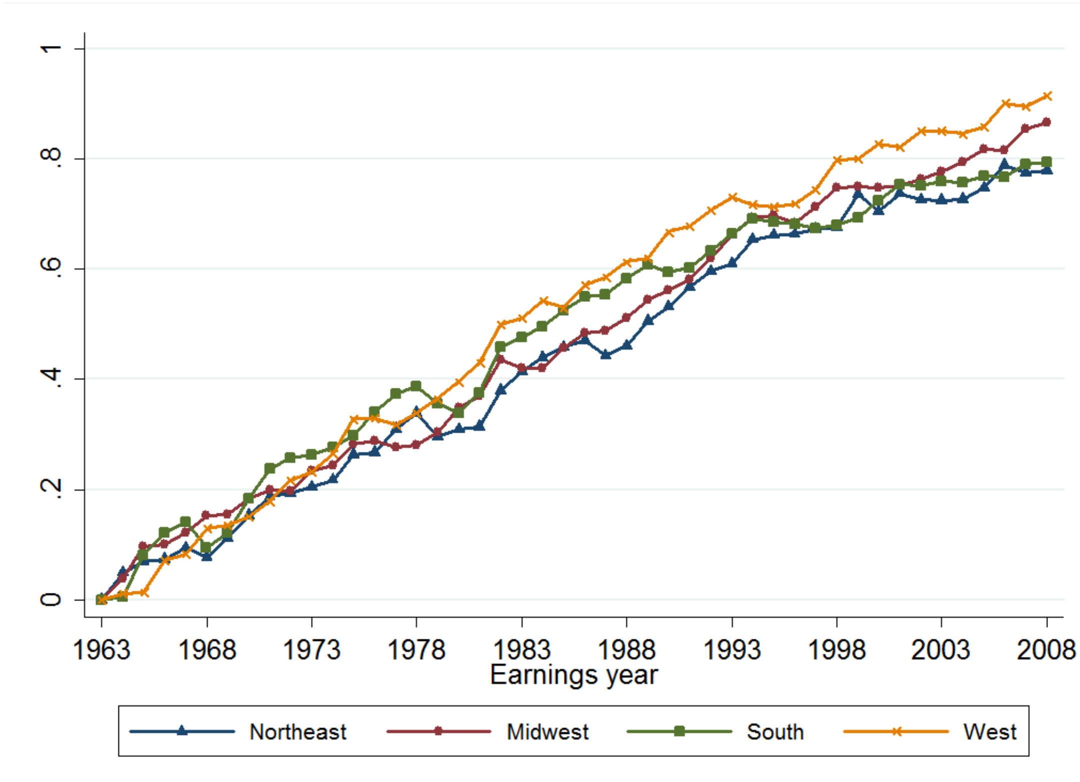
	(1)	(2)	(3)
$\ln(H^C_{rt}/H^{HS}_{rt})$ X Northeast	-0.239	-0.396	-0.486
	[0.082]**	[0.097]**	[0.092]**
$\ln(H^C_{rt}/H^{HS}_{rt})$ X Midwest	-0.385	-0.448	-0.499
	[0.070]**	[0.086]**	[0.081]**
$\ln(H^C_{rt}/H^{HS}_{rt})$ X South	-0.340	-0.425	-0.416
	[0.113]**	[0.080]**	[0.074]**
$\ln(H^C_{rt}/H^{HS}_{rt})$ X West	-0.307	-0.670	-0.566
	[0.063]**	[0.065]**	[0.081]**
t X Northeast	0.007	0.018	0.013
	[0.004]*	[0.006]**	[0.005]*
t X Midwest	0.015	0.019	0.013
	[0.003]**	[0.005]**	[0.005]**
t X South	0.015	0.029	0.026
	[0.003]**	[0.003]**	[0.004]**
t X West	0.016	0.035	0.025
	[0.001]**	[0.003]**	[0.006]**
t^2 X Northeast		-0.008	0.041
		[0.004]*	[0.013]**
t^2 X Midwest		-0.004	0.038
		[0.004]	[0.013]**
t^2 X South		-0.024	-0.007
		[0.002]**	[0.013]
t^2 X West		-0.025	0.011
		[0.003]**	[0.019]
t^3 X Northeast			-0.007
			[0.002]**
t^3 X Midwest			-0.006
			[0.002]**
t^3 X South			-0.002
			[0.002]
t^3 X West			-0.005
			[0.002]+
N	184	184	184
R^2	0.995	0.998	0.998
Test on Equivalence of Elasticities			
F-stat for NE=MW=S=W	0.631	3.015	0.630
p-value	(0.596)	(0.032)	(0.596)
F-stat for S=NE	0.526	0.053	0.347
p-value	(0.469)	(0.819)	(0.557)
F-stat for S=MW	0.112	0.041	0.575
p-value	(0.739)	(0.841)	(0.449)
F-stat for S=W	0.067	5.666	1.866
p-value	(0.796)	(0.018)	(0.174)

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$

Table 3.2 reports the results from this estimation. The first column contains results for the 1963-2008 period using a linear trend specification for relative demand. We see estimates for elasticities and trend parameters are all significant at 1% level. The equivalence of elasticities of substitution between college and high school labour across regions is rejected. The second and third columns add to the specification quadratic and cubic trend terms, respectively. The fourth column used quadratic trend specification for the South and cubic specification for other regions. As with the standard approach in Table 3.1, we see that elasticity estimates for the South and West are very sensitive to inclusion of higher order polynomials. Unlike the standard approach in Table 3.1, we fail to reject the equality of elasticity of substitution between college and high school labour in Table 3.2, except in column which uses a quadratic trend for SBTC. The estimated elasticity of substitution is 1.8 ($\frac{1}{0.566}$) for the West and 2.4 ($\frac{1}{0.416}$) for the South. Testing equality of elasticities for different pairs of regions also shows that the difference between elasticity estimates for the South and West is statistically insignificant at 10% level.

Figure 3.8 shows the implied relative demand for college labour estimated using Equation (3.6) and parameter estimates in the third column of Table 3.2. The relative demand for college labour seems to follow a very similar pattern across regions. The estimated average annual growth in relative demand for college labour is around 2% for the West, 1.9% for the Midwest, 1.7% for the Northeast and South. The differences in rates of change in relative demand across regions are a lot smaller compared to those found by using standard approach. A supporting piece of evidence is provided by Carneiro and Lee (2011). They also relax the assumption of constant skills within groups, but use a different identification strategy: They identify skill level (quality) changes by comparing wages of workers in the same labour market, but were born in different regions, which have different college enrolment rates, and presumably different average quality of workers with any college college education.[22] They estimate similar demand patterns across regions.

Figure 3.8: Predicted Relative Demand for College Labour from the Estimation Using C-HS Relative Skill Prices and Quantities



In sum, results from the implementation of the model using a more general approach to estimating prices and quantities show that elasticity estimates are more similar across regions compared to the standard approach. Differences in elasticity estimates are found to be statistically insignificant. Moreover, relative demand patterns look very similar across regions in contrast to the standard approach. Therefore, different trends in relative price for college labour across regions, as shown in Figure 3.4.2, are mainly driven by differences in changes in relative supply of skills and differences, and not by differences in elasticities and changes in relative demand for college graduates across regions.

[22]They use a constant elasticity of substitution of 3.06 (which is higher than estimated here) between college and high school graduates across regions.

3.5 Conclusions

The dramatic increase in the college-high school wage gap during the 1980s gave rise to an extensive literature on understanding the sources of changes in the college wage premium. The model introduced by Katz and Murphy (1992) has been used extensively in the literature to explain the changes in wage structure over the last forty years. The canonical model used in the literature on national wage inequality is a model of supply and demand with two types of skills, where relative prices and skill quantities are determined.

The U.S. is made up of distinct local labour markets. In this chapter, I ask whether the canonical framework used at the national level can also help explain movements in relative prices at the local level. Few studies used the canonical model at the local level (Lindley and Machin (2013), Ciccone and Peri (2005)). The common finding is that there are significant differences in changes in relative demand for high-skilled labour across local markets. Labour markets in the South are found to have slower rates of growth in relative demand for skilled labour.[23]

In this chapter, I re-examine analyses from studies in the literature which use the standard approach to implementing the canonical model (composition-adjusted wages and hours as proxies for skill prices and supply) in light of the evidence from the second chapter. The second chapter argues that some of the problems in predictions of canonical model in the national wage inequality literature are mainly due to implementing the model using composition-adjusted wages and hours.

The main contribution of this chapter is to show that the canonical model yields very different implications when using a more general approach to implementation compared to the standard approach in the literature. The standard approach suggests divergent patterns for relative demand for college labour across regions, whereas the alternative approach

[23]Ciccone and Peri (2005) study skill price premium by comparing high school dropouts and those that have high school degree and more. In this chapter, high-skilled labour corresponds to college graduate labour.

reveals much closer patterns. Moreover, in contrast to the standard approach elasticities of substitution between college and high school labour are more similar across regions, and differences in elasticities are statistically insignificant depending on specification. In sum, changes in relative skill prices are mainly driven by changes in relative skill supply of college vs high school labour.

The alternative approach to implementing canonical model (also used in the second chapter) is less restrictive compared to the standard approach, which imposes constant skill levels for education-experience-gender groups over time. This approach reveals that there are in fact remarkable differences in movements of relative composition-adjusted wages (Figure 3.1) and relative skill prices estimated in Section 3.4.2 (Figure 3.5). Thus, it is a more sensible approach to implementing the canonical model. Although, one drawback of this approach could be that it need to make the assumption of perfect substitutability across different age groups. However, it is unlikely that this is a very strong assumption, because Card and Lemieux (2001) and Acemoglu and Autor (2011) allow for imperfect substitution across age groups, and they both find a high elasticity of substitution between different ages (around 3.7).

One concern with local level studies in this literature is selective migration. OLS estimates of elasticities could be biased due to internal migration across local markets. Ciccone and Peri (2005), who work at the state level, found that OLS and IV estimates are significantly different, and therefore it is important to instrument the relative supply variable.[24] Lindley and Machin (2013), who work at state and MSA level, also use IV estimation, but they do not comment how different OLS and IV estimates are. Carneiro and Lee (2011) uses Census-divisional labour markets (smaller than Census regions used in this chapter) in their analysis, and they found that migration across divisions are unlikely to

[24]They examine changes in relative price of high school graduates or more and high school dropouts, instead of changes in relative price of college vs high school labour.

drive their results. Inter-regional migration rates are smaller than inter-divisional migration rates. Therefore, Census regions are more contained like the national market compared to states or MSAs, which has more populations flows among them. Given the evidence from Carneiro and Lee (2011) that inter-divisional migration does not confound estimates, and the fact that inter-regional migration rates are low (around 2% and 1% for college and high school graduates), migration is unlikely to be an issue for the analysis in this chapter.

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Chapter 4

Implications of Limited Mobility for Local Wages: Recent Evidence from the United States

4.1 Introduction

Less-educated workers experienced significant decreases in their earnings during 1980s. On the other hand high-educated workers' earnings increased which contributed to a rapid increase in overall wage inequality during this period. The literature on explaining this divergence between the wages of high and low educated labour started to grow in the early 1990s. Demand explanations, which have been very popular, simply suggest that demand for less educated labour has declined as the economy became more technologically advanced. Topel (1997) notes that increased participation of women and increased immigration of low-skilled labour to the US are among the supply-side explanations. Apart from demand and supply explanations at the national level that are frequently seen in the literature, researchers also exploited local variations in demand shifts to understand the determinants of wage levels of high and low-educated labour or local wage inequality, as measured by the difference between 90^{th} and 10^{th} percentile of the log wage distribution (Bound and Holzer (2000) and Bernard and Jensen (2000), respectively). Different local labour markets have different concentration of industries which means that some are affected disproportionately by aggregate demand shocks. For example, the unemployment rate increased by 18.3% in Michigan, 19.6% in Missouri, and 21.1% in Louisiana, whereas it increased by only 8.1% in Alaska, 3.8% in North Dakota, and decreased by 7.3% in Oklahoma in 2008. Conditional on observable characteristics that affect wages, variations in the relative demand across regions or states can help identify the effects of demand shifts on local wage levels.

Given variation in demand shifts across states, one can think of subsequent supply adjustments that could occur across states and their consequences on local labour market outcomes of different demographic groups. For example, when a *skill neutral* negative demand shock hits the local labour market, the resulting decrease in wages will generate a tendency for workers to migrate out of that local labour market and to find another job in other markets where conditions are less severe. On a related note, Kennan and Walker (2009) finds that expected income is a significant factor in understanding the migration behaviour of individuals. Local demand shocks affect current income as well as future income prospects depending on the persistence of these shocks. When there is perfect mobility, following a negative demand shock to the local economy, the wage levels of high and low skilled labour do not change at all. However, some people may not be willing to migrate due to personal reasons, financial reasons, or lack of information about other job opportunities in distant markets. Therefore, some groups of people will be more able to shift their labour supply to another location following a negative local demand shock.

Some studies present evidence on different mobility rates for different demographic groups. Mobility rates of high-educated and/or younger people are found to be higher than that of low-educated and/or older people (Greenwood (1975), Wozniak (2010)). Following a negative local demand shock, these differences in mobility rates will cause an increase in the relative supply of low-educated workers within the local market and consequently, relative wage of this less-mobile group will decrease more than more mobile workers in that local market. Bound and Holzer (2000) and Topel (1986) find supporting evidence for the potential effects of differential mobility on local wage levels. Topel (1986) uses the deviation of detrended natural logarithm of state aggregate non-agricultural employment from detrended logarithm of national aggregate non-agricultural employment as proxy for local demand shocks. Using data from the Current Population Survey, he shows that for the period 1977-1980 the magnitude of the effects of local demand shocks on wages are larger for less mobile groups such as the lower-educated. Bound and Holzer (2000) use growth in total local hours as a proxy for local demand shifts. They instrument growth in total local hours with a measure which reflects shifts in industrial composition within the local market, which is defined by Metropolitan Statistical Area. Using Census data for 1980 and 1990, the authors find that earnings and employment decrease more for the less educated and/or black males following a negative local demand shift and less-educated and more-experienced people show lower magnitudes of supply adjustments following these demand shifts.

In this chapter, the aim is to conduct a similar study for the more recent period to see whether we still see significant effects of local demand shocks on local wage levels in the short term, and how differently these education groups are affected by these local demand shocks. This chapter is motivated by the changes in mobility patterns in college and high school graduates during the 2000s compared to the 1980s and 1990s. Annual inter-state mobility rates for college graduates were on average 2.5-2.6% higher than that of high school graduates during the 1980s and 1990s, while this difference in mobility rates came down to around 1.6% on average during the 2000s. Given this convergence in mobility rates of college and high school labour, it is important to ask if there are still significant differences in how wages of these groups respond to local labour demand shocks.

Local markets are defined by states. The extent of differences in wage effects of demand shocks across groups, if any, could be related to differences in the ability to shift labour supply from one state to another in the short term between different education groups. The main focus will be on differences between high school and college graduates.

Using data from March files of the Current Population Survey (CPS), I estimate the effect of local demand shocks on wages of male high school and college graduates for periods 1980-1989, 1990-1999 and 2000-2007. I follow Topel (1986) in constructing a measure for local demand shocks. I find that wage effects of local demand shocks decline over time for both high school and college graduates. However, decline in wage effects is more dramatic for high school graduates. Moreover, effect of shocks are significantly higher for high school graduates for the 1980s and 1990s, but this difference in wage effects has disappeared in the 2000s: One standard deviation decrease in local demand shocks corresponds to 4.7%, 2.6% and 1% decrease in high school wages in the 1980s, 1990s and 2000s, respectively. For college graduates, wage effects in the 1980s, 1990s and 2000s are estimated as 2.7%, 1% and 1%. The important finding in this chapter is that this evidence for equalization of wage effects of local shocks on high school and college graduate wages is accompanied by converging mobility rates between the two education groups. This also confirms previous evidence (Topel (1986), Bound and Holzer (2000)) on the importance of labour supply adjustments across local markets following local demand shocks for wage changes.

Section 4.2 discusses some of the important work in this area. Section 4.3 describes the data used in this chapter. Section 4.4 gives a descriptive analysis, explains the empirical framework and presents the results for wage regressions. Section 4.5 concludes.

4.2 Existing Literature

Literature on understanding the consequences of limited mobility for the effects of local demand shocks on wages of different groups is not very extensive. Topel (1986) and Bound and Holzer (2000) are among the few studies that attempt to understand the implications of different mobility rates for labour market outcomes. Bernard and Jensen (2000) explores the negative effects of local demand shocks on regional wage inequality. Cadena and Kovak (2013) study the responsiveness of Mexican workers to changes in local demand, and how their mobility across local markets would affect local native workers' labour market outcomes. I will discuss the results of the former two studies as they relate more to the content of this chapter.

Topel (1986) is one of the first papers to develop a spatial model of wage and employment determination in a dynamic setting. In his model, the local dynamics are driven by shocks to factor productivity (demand), which is not biased towards any kind of production factor, within a locale. Heterogeneity is added to the model by assuming that there are different types of experience cohorts which have different costs of mobility. Each type of worker's objective is to maximize his discounted lifetime wealth by choosing the location they want to work in, which can be seen as an investment decision. Future local economic conditions are to be forecasted by the workers before deciding on location, therefore equilibrium dynamics are characterized by forward-looking behaviour. This implies that local changes in labour demand will have deeper consequences on wage and employment dynamics of workers with higher mobility costs. Topel's model also implies that the elasticity of inter-area supply of workers is larger for permanent demand shifts than transitory ones.

Topel (1986) tested the implications of his model using the Current Population Survey for the period 1977-1980. The state is chosen as the geographical unit of study and the indices for local demand shock are taken simply as the deviation of detrended natural logarithm of state aggregate non-agricultural employment from detrended logarithm of national aggregate non-agricultural employment.[1] The expectations of individuals about future demand shocks are generated by forecasting future demand shocks using an AR(2) regression of the local demand shock variable. The linear regression results of log real weekly wages show that the effects of local demand shocks on wages are strong even in the short run. Moreover, magnitudes of these effects are larger for less mobile groups, such as the low-educated. Topel (1986) also finds that wage effects increase when predicted future local demand disturbances are included in regressions. This constitutes indirect evidence for the importance of expectations for mobility decisions (i.e. subsequent supply adjustments after a local demand shock), which affect the extent of these local demand shock effects on wages.

Bound and Holzer (2000) test the implications of mobility differences for regional wage levels by running separate wage, employment and population adjustment regressions for each education-experience-race group using Census data for the years 1980 and 1990. Dependent variables in their regressions are *changes* in these labour market outcomes and population from 1980 to 1990. Metropolitan Statistical Areas (MSA) are considered as local labour markets. The authors use growth in total local hours as a proxy for local demand shifts. They instrument growth in total local hours with a measure which reflects shifts in industrial composition within the locale. For each MSA, they create a demand index which is a weighted average of the nationwide growth of total hours worked in industries, where the weight is the share of total hours worked accounted for by that industry in that MSA. The authors find that earnings and employment decreases more for the less educated and/or black males following a negative local demand shift, and that less-educated and more-experienced workers show lower magnitudes of supply adjustments following these demand shifts.

[1] Quadratic trend is used in the regressions of log non-agricultural employment.

This evidence highlights the importance of limited supply adjustments for changes in local wages of different groups. This suggests that adverse effects of demand shifts are worsened for groups with limited mobility across local labour markets. Limited mobility and changes in education distribution constitute channels of supply effects on wage gaps between education groups. In this chapter, I will focus on the implications of limited supply adjustments of high school graduates for the college-high school wage gap rather than effects of changes in the education distribution.

4.3 Data

This chapter uses cross-sectional data from the Current Population Survey (CPS) for the earnings period 1980-2007. The annual demographic March CPS files contain extensive information on many labour market variables as well as other demographic variables. The sample used in the analysis consists of male workers who are not self-employed, who worked at least 40 weeks in the year and are between 18 and 64 years old. These individuals presumably have the strongest labour force attachment. I also exclude individuals who are either in the bottom or top second percentile of the nominal wage distribution. I use two different price indices: Before 1985, national consumer price index for all urban consumers (CPI-U) is used, whereas after 1985 and on regional consumer price indices are used.

Respondents are asked their state of residence in the interview year as well as in the previous year. This information is used to generate a yearly migration variable. People who lived abroad in the previous year are excluded from the sample since we are only interested in inter-state migration in the US. This migration variable is used to calculate the population outflows and inflows for each state by education group. I compute the *weighted* count of people who moved in to and out from each state for each year using individual sampling weights to get estimates for population counts for people who migrated out or in a state.

These counts are used to compute net flows by state for high school and college graduates, which are then used to compute annual net migration rates for each of these education groups. Net migration rate in a year for an education group for a state is calculated by taking the ratio of net flow and population of that education group in the state in that year.

I estimate the effect of local demand shocks on log real wages of high school and college graduates for three time periods: 1980-1989, 1990-1999 and 2000-2007. Topel (1986) uses the deviation of detrended natural logarithm of state aggregate non-agricultural employment from national detrended employment as proxy for local demand shocks. Bound and Holzer (2000) use instrumented growth in total local hours as proxy for local demand shifts, where the instrument is a measure that reflects shifts in industrial composition within local markets defined by Metropolitan Statistical Areas. In this chapter, I examine short-term wage effects of local demand shocks, as in Topel (1986) which studies the period 1977-1980. For comparability, I follow Topel (1986) in constructing local demand shocks. I use annual levels of log total non-agricultural employment for the United States and for each state for the period 1950-2009 from Bureau of Labour Statistics (BLS). Then, I detrend the national and state-level employment levels with a quadratic trend and compute the deviation of detrended state-level employment from its national counterpart. The reason for using data on employment starting from 1950 is to get more reliable estimates in the detrending regressions. These state-level deviations in detrended log employment from their national counterparts will be used as a proxy for local demand shocks. This variable will involve shocks to labour demand as well as shocks to labour supply. There is a positive association between this shock variable and log real wages, which implies that the shock variable picks more of demand shocks rather than supply shocks. However, it should be noted that magnitudes of wage effects could be sensitive to the extent the demand shock variable picks up supply versus demand shifts.

In the descriptive analysis below, I compute percentage changes in state relative real weekly wage levels for high school and college graduates males. I use the Integrated Public Use Microdata Samples (IPUMS) of the Census data files (5% samples) for years 1980, 1990 and 2000, and American Community Survey (2008). The reason Census data is used instead of CPS to compute these changes is due to its large sample sizes. Relative wages in a state for an education group are computed by taking the ratio of mean real wage for that education group in that state and the national mean wage level for that education group.

I also compute relative unemployment rates and percentage changes in relative total non-agricultural employment levels for each state which are obtained from the Bureau of Labor Statistics (BLS).

4.4 Empirical Framework and Results

This section will first give a descriptive analysis which show associations between local unemployment rates, employment levels, real wage levels and mobility rates. The second subsection presents and discusses the estimation results for effects of local demand shocks on log real weekly wages of high school and college graduates.

4.4.1 Descriptive Analysis

Table 4.1 shows the distribution of unemployment rates across states, and how it evolved over the 1980-2007 period. Reported numbers are averages of ratios of local unemployment rates to national unemployment rates over the indicated period. There are striking differences across states in unemployment rates which persist over time. Correlations between different periods are around 0.65-0.70. Southern states tend to remain below national levels while some states in the Northeast and Midwest remain above national levels.

Table 4.2 shows average annual changes in state average wages relative to national wages over the 1980s, 1990s and 2000s for high school and college graduates. Fluctua-

Table 4.1: Average Relative Unemployment

State	1980-1989	1990-1999	2000-2007
Alabama	1.28	0.95	0.88
Arizona	0.94	0.96	0.94
Arkansas	1.15	0.99	1.00
California	0.99	1.29	1.15
Colorado	0.89	0.77	0.92
Connecticut	0.65	0.90	0.86
Delaware	0.76	0.77	0.75
Florida	0.89	1.05	0.90
Georgia	0.86	0.87	0.92
Idaho	1.03	0.95	0.85
Illinois	1.19	1.02	1.11
Indiana	1.12	0.76	0.95
Iowa	0.91	0.65	0.76
Kansas	0.70	0.75	0.92
Kentucky	1.22	1.01	1.10
Louisiana	1.39	1.12	1.02
Maine	0.82	1.00	0.88
Maryland	0.77	0.89	0.80
Massachusetts	0.70	1.01	0.91
Michigan	1.49	1.08	1.27
Minnesota	0.82	0.70	0.85
Mississippi	1.39	1.18	1.27
Missouri	0.97	0.87	0.99
Montana	1.00	1.00	0.80
Nebraska	0.61	0.46	0.66
Nevada	0.98	0.96	0.98
New Hampshire	0.57	0.83	0.72
New Jersey	0.83	1.08	0.94
New Mexico	1.14	1.18	0.96
New York	0.91	1.15	1.03
North Carolina	0.84	0.79	1.06
North Dakota	0.72	0.64	0.63
Ohio	1.21	0.96	1.08
Oklahoma	0.90	0.88	0.84
Oregon	1.16	1.02	1.25
Pennsylvania	1.08	1.02	0.98
Rhode Island	0.79	1.10	1.03
South Carolina	0.95	0.93	1.17
South Dakota	0.65	0.58	0.63
Tennessee	1.14	0.94	1.02
Texas	0.96	1.07	1.04
Utah	0.89	0.69	0.82
Vermont	0.69	0.81	0.74
Virginia	0.72	0.77	0.67
Washington	1.17	1.02	1.13
West Virginia	1.67	1.47	1.00
Wisconsin	0.98	0.71	0.92
Wyoming	0.91	0.89	0.72

tions in wages are generally larger during the 1980s compared to other periods for both high school and college graduates. Magnitudes of changes in relative wages of high school graduates are larger than that of college graduates during the 1980s. Figures 4.1 and 4.2 show relative unemployment rates and relative wage changes, and changes in relative unemployment rates and changes in relative wages for high school and college graduates. There is a strong association between relative wage changes and unemployment rates, and correlation between the two series is stronger for high school graduates, especially during the 1980s (-0.54 vs -0.30). Many states with persistent low unemployment rates in the Northeast show increases in high school wages, while those with persistently high unemployment rates, such as Michigan, Louisiana, Ohio, Indiana and Illionois, saw decreasing relative wages for high school graduates. Moreover, Figure 4.2 shows that overall pattern of relative wage changes conforms with changes in relative unemployment rates. States with decreasing relative unemployment rates tend to exhibit increasing relative wages. Given that high school graduates show larger fluctuations in their wages compared to college graduates, especially during the 1980s, it could be that they are more sensitive to changes in local labour market conditions.[2]

Table 4.3 shows the changes in geographic location of employment. Many states in the Midwest such as Michigan, Ohio, Iowa, Indiana, Illinois and Wisconsin, and some in the Northeast such as Massachusetts, Pennsylvania, New York and Connecticut, saw declining employment levels during the 1980s, while several states in the South and West such as California, North Carolina, South Carolina, Texas and Arizona saw increasing employment levels. This pattern generally follows throughout the 1990s and 2000s. Overall, it seems that the distribution of employment shifted from states in the Midwest and Northeast to

[2]Bound and Holzer (2000) find that wages of high school graduates and those with less than high school degree are affected more by local adverse demand shocks compared to college graduates in the 1980s. They define local markets by Metropolitan Statistical Areas, and they look at 10-year changes in wages from 1980 to 1990 using U.S. Census data.

states in the South and West during the 1980-2007 period. Changes in relative employment levels shown in Table 4.3 might reflect supply as well as demand changes, but Tables 4.2 and 4.3 show that most of the time changes in relative employment levels and changes in relative wages are positively associated.

Table 4.4 shows average annual net migration rates for high school and college graduates.[3] The pattern of net migration rates generally conforms with that of changes in relative employment levels in Table 4.3. During the 1980-2007 period, population flows to many of the Southern states while there are significant population outflows from several states in the Midwest and the Northeast. Magnitudes of population shifts are generally larger for college graduates compared to high school graduates, especially during the 1980s. These population outflows by college graduates may have dominated some of the adverse effects of local demand shocks in these states. Moreover, for some states population flows by high school graduates are in opposite direction of what one would expect during the 1980s. For example, Michigan, Ohio and Missouri took a big hit during this period as they are mostly concentrated in manufacturing industry. We see that there are population flows to these states by high school graduates, while there are significant population outflows by college graduates.

As shown in previous studies (Greenwood (1975), Bound and Holzer (2000), Wozniak (2010)), college graduates are more mobile than high school graduates. However, differences inter-state mobility are decreasing over time. Figure 4.3 shows average annual inter-state migration rates for high school and college graduates over the 1980s, 1990s and 2000s. There is a decline in mobility for both education groups, but college graduates show a more dramatic decrease in their mobility during the 2000s. Differences in inter-state mi-

[3] Inter-state mobility data is available in CPS staring in 1982. For a given year, net migration rate for an education group for a state is calculated by taking the ratio of difference between total number of people who moved into the state and moved out of the state in that year, and the population for that education group in that year. Negative net migration rates indicate population outflows and positive rates imply inflows.

gration rates are around 2.5-2.6% for the 1980-1999 period, while it is around 1.6% in the 2000s.

The descriptive analysis here suggests that most states with improving (deteriorating) labour market conditions saw increasing (declining) relative wages and population inflows (outflows). Fluctuations in high school wages are greater than that of college graduates, who also exhibit larger population outflows from states with deteriorating market conditions (e.g. Michigan, Ohio, Wisconsin), especially during the 1980s, a period of economic downturn. Lower magnitudes of relative wage changes for high school graduates after the 1980s is accompanied by decreasing differences in inter-state mobility rates between high school and college graduates. Declining differences in inter-state mobility and lower magnitudes of changes in relative wages in the 2000s compared to the 1980s, could suggest different implications for the responsiveness of high school graduate wages to local demand shocks compared to what is found by previous studies (Topel (1986), Bound and Holzer (2000)).

In the next subsection, I present results from log real weekly wage regressions on local demand shocks along with other observable characteristics.

4.4.2 Effect of Local Market Conditions

In this subsection, I look at the effects of local labour demand shocks on wages of high school and college graduates. We do not directly observe changes in demand for labour, therefore a proxy for local demand shifts need to be found. Bound and Holzer (2000) uses growth in total local hours, which they instrumented with a measure that reflects shifts in industrial composition within a locale, as a proxy for local demand shifts. Topel (1986) uses *detrended* annual levels of log total non-agricultural employment for the United States

Table 4.2: Average Annual Changes in Relative Wages

State	HIGH SCHOOL GRADUATE 1980-1990	HIGH SCHOOL GRADUATE 1990-2000	HIGH SCHOOL GRADUATE 2000-2007	COLLEGE GRADUATE 1980-1990	COLLEGE GRADUATE 1990-2000	COLLEGE GRADUATE 2000-2007
Alabama	-0.40	0.13	0.05	-0.03	-0.21	-0.36
Arizona	-0.71	0.50	0.11	0.20	0.16	-0.20
Arkansas	-0.41	0.59	-0.33	-0.88	0.38	-0.34
California	1.33	-0.49	-0.39	0.47	0.15	0.17
Colorado	-0.75	0.97	0.13	-0.61	0.33	0.25
Connecticut	2.55	-0.65	-0.36	0.65	0.10	-0.13
Delaware	0.44	0.33	-0.44	0.60	-0.36	-0.31
Florida	0.35	0.15	0.26	0.11	0.09	-0.43
Georgia	0.57	0.22	-0.12	0.06	0.30	-0.07
Idaho	-0.26	0.08	0.49	-1.01	0.00	-0.11
Illinois	-0.59	0.06	-0.39	-0.01	0.05	-0.21
Indiana	-0.79	0.34	-0.52	-0.51	-0.01	-0.57
Iowa	-1.09	0.15	0.31	-1.27	0.15	0.01
Kansas	-0.36	0.14	-0.03	-0.44	-0.05	-0.25
Kentucky	-0.69	0.35	-0.23	-0.03	0.00	-0.35
Louisiana	-1.25	0.47	1.18	-0.76	-0.37	-0.22
Maine	1.11	-0.49	0.60	0.64	-0.31	-0.13
Maryland	0.93	-0.35	0.81	-0.08	0.05	0.29
Massachusetts	2.40	-0.57	0.13	0.95	0.26	0.16
Michigan	-0.84	0.04	-1.01	-0.69	0.18	-0.56
Minnesota	-0.41	0.17	-0.20	-0.61	0.17	0.23
Mississippi	-0.46	0.35	0.10	-0.49	-0.01	-0.52
Missouri	-0.76	0.23	0.10	-0.48	-0.22	-0.17
Montana	-0.82	-0.46	1.15	-1.08	-0.62	0.51
Nebraska	-1.01	0.75	-0.23	-1.02	0.07	-0.27
Nevada	0.41	0.33	0.37	0.00	-0.17	-0.44
New Hampshire	1.81	-0.38	0.26	0.86	-0.03	0.20
New Jersey	1.97	-0.26	-0.40	0.63	0.09	-0.03
New Mexico	-0.96	0.16	0.81	-0.75	-0.24	-0.60
New York	0.90	-0.49	0.11	0.58	-0.06	-0.29
North Carolina	0.54	0.65	-0.21	0.01	0.39	-0.01
North Dakota	-0.55	-0.27	1.64	-1.14	-0.10	0.43
Ohio	-0.78	0.04	-0.48	-0.29	-0.20	-0.15
Oklahoma	-0.69	0.04	0.20	-0.74	-0.37	-0.45
Oregon	-1.00	0.22	-0.42	-0.53	0.32	-0.06
Pennsylvania	-0.26	-0.14	0.10	0.18	-0.27	-0.03
Rhode Island	1.73	-0.32	0.40	0.64	0.00	-0.30
South Carolina	0.36	0.43	-0.32	0.08	-0.30	-0.26
South Dakota	-0.31	0.30	0.06	-1.25	0.33	-0.44
Tennessee	-0.19	0.28	-0.32	-0.12	-0.30	-0.31
Texas	-0.66	0.41	0.18	-0.36	0.37	-0.13
Utah	-0.45	0.29	0.13	-0.58	0.39	-0.25
Vermont	1.36	-0.62	0.67	0.26	-0.39	0.03
Virginia	0.70	-0.25	0.45	-0.45	0.09	0.76
Washington	-0.52	0.27	0.40	-0.46	0.28	0.73
West Virginia	-1.02	-0.72	0.66	-0.73	-0.52	-0.54
Wisconsin	-0.58	0.47	-0.30	-0.48	0.16	-0.28
Wyoming	-1.27	-0.95	1.88	-1.85	-0.39	-0.51

Figure 4.1: Relative Unemployment vs Relative Wage Changes By Education

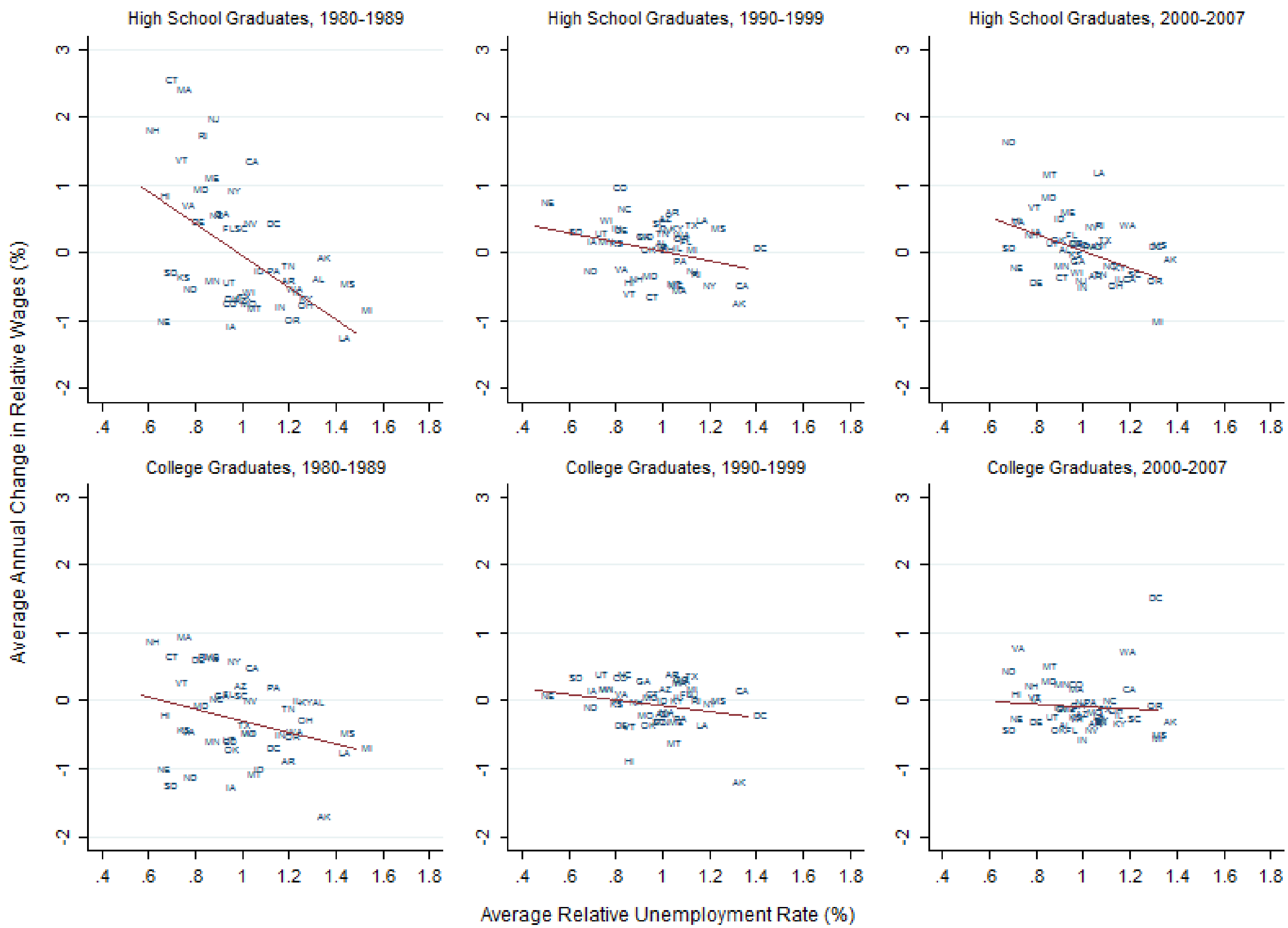


Figure 4.2: Relative Unemployment Changes vs Relative Wage Changes By Education

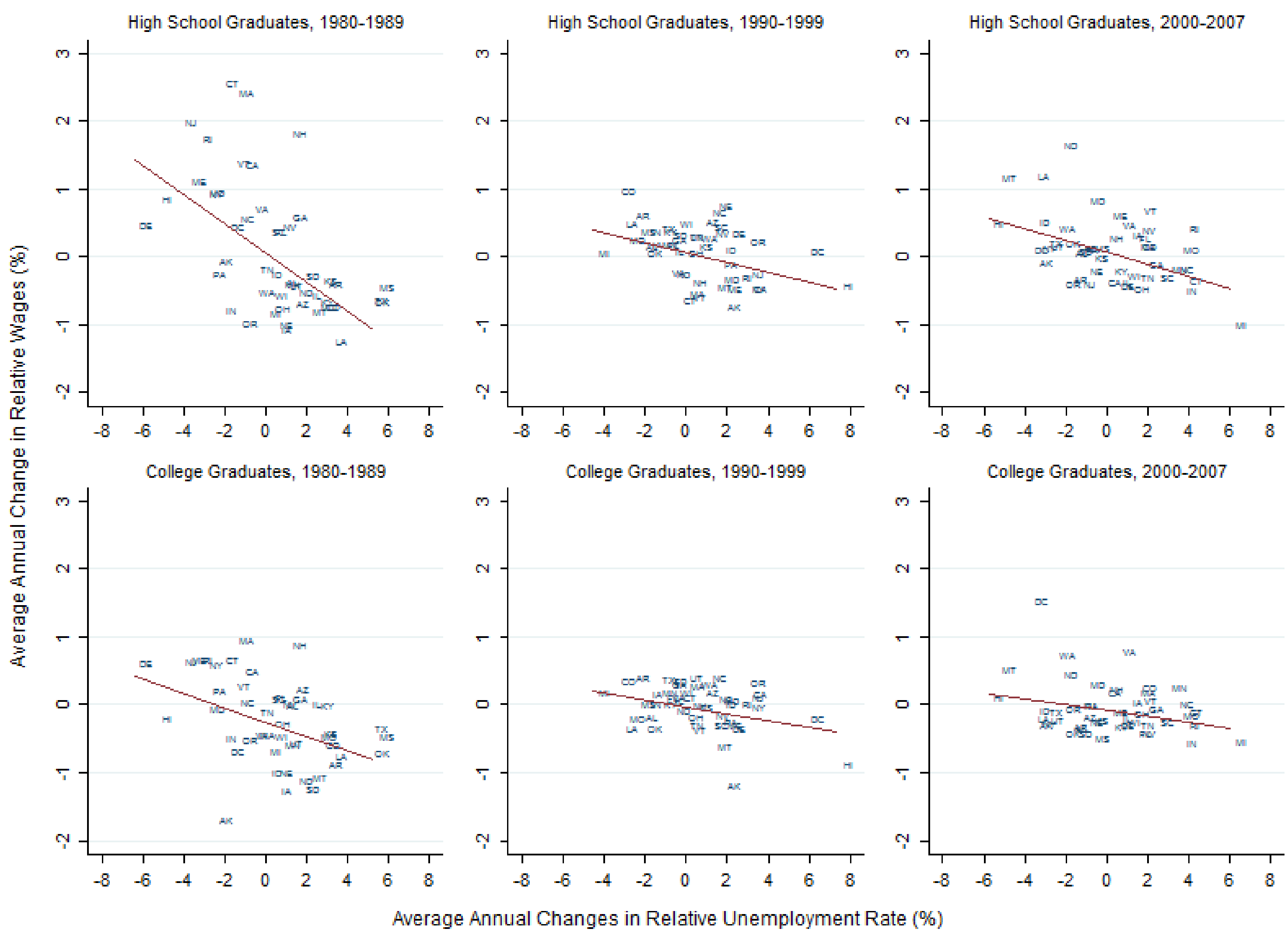
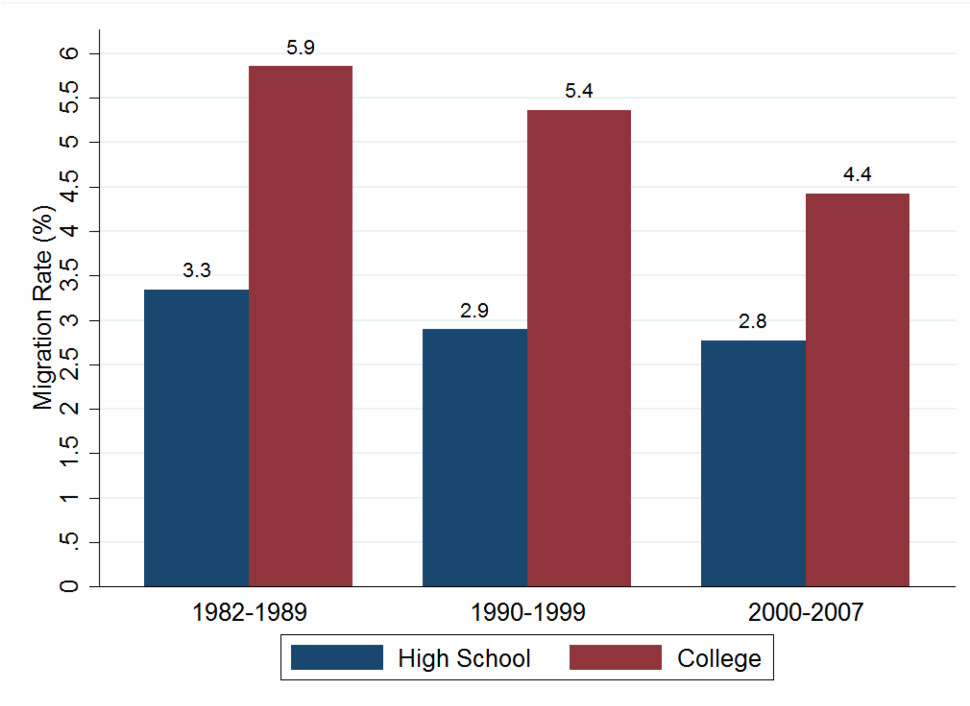


Table 4.3: Average Annual Changes in Relative Employment Levels

State	1980-1990	1990-2000	2000-2007
Alabama	-0.21	0.04	-0.26
Arizona	2.16	2.22	1.86
Arkansas	-0.07	0.69	-0.14
California	0.53	-0.43	0.21
Colorado	0.15	1.88	0.31
Connecticut	-0.07	-1.73	-0.59
Delaware	1.12	0.04	-0.12
Florida	2.63	0.82	1.24
Georgia	1.42	0.94	0.10
Idaho	-1.02	2.13	1.64
Illinois	-1.16	-0.44	-0.76
Indiana	-0.78	0.03	-0.73
Iowa	-1.23	0.25	-0.38
Kansas	-0.66	0.45	-0.33
Kentucky	-0.42	0.48	-0.32
Louisiana	-1.64	0.31	-0.65
Maine	0.82	-0.98	-0.15
Maryland	0.60	-0.73	0.28
Massachusetts	-0.02	-1.36	-0.66
Michigan	-1.04	-0.21	-1.68
Minnesota	-0.17	0.51	-0.12
Mississippi	-0.90	0.50	-0.80
Missouri	-0.42	-0.14	-0.50
Montana	-1.56	1.00	1.06
Nebraska	-0.68	0.56	0.05
Nevada	2.36	3.56	2.66
New Hampshire	1.54	-0.40	0.00
New Jersey	0.15	-1.21	-0.25
New Mexico	0.16	0.84	1.02
New York	-0.44	-1.51	-0.41
North Carolina	0.76	0.48	0.12
North Dakota	-1.17	0.41	0.46
Ohio	-1.10	-0.33	-1.11
Oklahoma	-1.09	0.45	0.15
Oregon	-0.49	0.98	0.29
Pennsylvania	-1.15	-0.93	-0.34
Rhode Island	-0.39	-1.67	-0.09
South Carolina	0.60	0.22	-0.05
South Dakota	-0.48	1.18	0.36
Tennessee	0.16	0.37	-0.29
Texas	0.20	1.15	0.78
Utah	0.49	2.43	1.44
Vermont	0.97	-0.69	-0.10
Virginia	1.20	-0.01	0.41
Washington	0.76	0.82	0.47
West Virginia	-2.49	-0.11	-0.26
Wisconsin	-0.51	0.42	-0.36
Wyoming	-2.10	0.13	1.90

Figure 4.3: Average Annual Inter-State Migration Rates



and for each state to compute the deviation of detrended state-level log employment levels from their national counterpart. This deviation of state-level residual log employment from its national counterpart is used as local demand shifts. I take each state as a distinct local labour market, and I follow Topel (1986) in constructing a variable for local labour demand shocks for comparability. Relative demand shocks in state s in year t are defined as:

$$\epsilon_{st} = \upsilon_{st} - \upsilon_t$$

where υ_{st} and υ_t are the residual series from the regression of log employment in state s in year t and log employment in the US in year t on a quadratic trend, respectively.[4] Table 4.5 shows standardized predicted relative demand shocks averaged over selected periods. There is substantial variation in relative demand shocks across states within a year. For

[4]Regressions for detrending are run separately for each state.

Table 4.4: Average Annual Net Migration Rates *(per 1000 population)*

	HIGH SCHOOL GRADUATE			COLLEGE GRADUATE		
State	1982-1989	1990-1999	2000-2007	1982-1989	1990-1999	2000-2007
Alabama	-2.5	11.2	5.2	-22.6	-10.2	0.5
Arizona	13.6	-5.8	18.5	6.0	-9.0	0.3
Arkansas	-6.7	-4.1	-5.4	1.7	6.1	5.9
California	-4.4	-8.6	-2.9	-1.9	1.6	-1.5
Colorado	0.7	15.8	4.6	-10.0	-4.3	24.0
Connecticut	-8.6	2.2	16.4	11.7	5.3	6.4
Delaware	0.1	1.2	-13.5	5.6	24.7	-10.0
Florida	18.3	10.9	9.3	7.9	7.2	10.1
Georgia	9.9	8.1	9.5	13.4	3.4	7.9
Idaho	2.4	16.0	9.7	9.0	4.5	-8.6
Illinois	-5.8	-5.3	-0.8	-5.4	-2.3	-12.0
Indiana	6.4	8.8	8.6	8.6	-4.3	-15.2
Iowa	9.3	0.7	8.4	-42.4	0.2	10.3
Kansas	-23.7	-6.6	-1.3	19.9	12.7	-13.5
Kentucky	-3.8	0.0	13.7	17.8	3.3	3.6
Louisiana	-9.2	1.6	-9.6	-15.9	-16.2	-7.1
Maine	5.5	12.4	-5.1	16.9	-11.8	-9.2
Maryland	-8.5	4.5	-6.0	17.4	7.2	-9.7
Massachusetts	1.6	-4.9	5.3	3.7	-8.7	0.7
Michigan	1.0	-4.7	-5.2	-11.3	-2.2	0.7
Minnesota	2.5	-0.3	8.5	15.6	19.3	4.7
Mississippi	-8.1	1.8	-22.3	-17.4	-12.7	-9.4
Missouri	8.6	13.2	4.7	-10.2	1.6	21.7
Montana	-25.8	-9.0	-0.7	17.9	-21.8	-0.5
Nebraska	-5.1	-13.4	-13.3	11.0	-14.9	-35.7
Nevada	9.4	15.7	20.8	55.3	23.0	19.4
New Hampshire	23.8	15.1	-11.2	46.8	12.2	3.6
New Jersey	0.4	-9.1	-2.0	-1.9	1.7	-1.2
New Mexico	-0.8	6.0	-5.1	-8.2	0.5	9.0
New York	-11.5	-8.6	-14.0	-14.4	-15.1	-6.2
North Carolina	0.9	-3.3	0.1	6.2	-0.8	4.5
North Dakota	-33.2	-25.8	-38.7	-68.2	-73.7	-4.6
Ohio	2.0	1.5	-1.9	-9.5	-3.7	-10.0
Oklahoma	-2.5	12.1	3.5	-26.7	13.2	-24.1
Oregon	0.8	2.6	-6.8	-11.6	39.6	10.4
Pennsylvania	-3.6	1.3	-0.8	-13.1	-8.3	-0.8
Rhode Island	-1.5	-17.0	-25.4	-49.3	-24.9	-2.8
South Carolina	19.4	-6.1	15.1	0.6	3.4	-15.7
South Dakota	13.3	1.2	-47.2	4.8	-19.6	-31.6
Tennessee	9.0	1.2	11.3	-8.1	42.5	7.4
Texas	2.4	3.7	3.1	19.3	3.5	4.7
Utah	10.1	10.7	1.7	-38.8	-14.2	-25.9
Vermont	-12.7	-2.3	-47.9	8.0	1.1	33.3
Virginia	-1.0	-2.5	0.6	41.2	-5.7	9.4
Washington	21.4	15.3	-0.8	25.1	22.9	16.3
West Virginia	-24.5	12.7	2.3	-64.7	-19.5	-13.1
Wisconsin	-2.9	-3.3	1.7	-13.4	7.7	-5.3
Wyoming	-31.3	-46.6	-15.4	-38.9	-40.5	-35.7

example, in 1980-1984 period New York, Pennsylvania, Michigan, Indiana, Illinois, Iowa and Ohio were hit by local negative demand shocks, whereas California, Colorado, Massachusetts, New Hampshire, Oklahoma, Texas and Vermont saw positive demand changes. States in the Midwest seem to have recovered during the 1990s and early 2000s, but most of these states are affected by economic downturn in the 2000s.

Given these relative demand shocks, I estimate the effect of local demand shocks on log real weekly wages of high school and college graduates for periods 1980-1989, 1990-1999 and 2000-2007. Log wage regressions are specified as:

$$\begin{aligned}\ln w_{iest} =& \beta + \beta_{\epsilon}\epsilon_{st} + \beta_{\epsilon e}D_{ie}\epsilon_{st} + \beta_{e}D_{ie} + \beta_{x}X_{i} + \beta_{z}Z_{st} + \beta_{ze}D_{ie}Z_{st} \\ &+\beta_{s}D_{is} + \beta_{t}D_{t} + \beta_{d}D_{id} + \eta_{iest}\end{aligned} \tag{4.1}$$

where $\ln w_{iest}$ is log real weekly wage for individual i with education level e, in state s in year t, ϵ_{st} is relative demand shock in state s, D_{ie} are education dummies, X_i contains experience and its polynomials up to quartic term, race, and marital status, Z_{st} contains *predicted* growth rate of log non-agricultural employment and *predicted* average future local demand shocks, D_{id} are 2-digit industry dummies, D_{is} are state dummies, and D_t are year dummies. Predicted employment growth variable can pick some of the trend demand changes as well as supply changes.

According to Topel (1986), expectations of future local demand shocks will affect current wages through migration. An increase in expected future demand increases current in-migration with the expectation of future wage gains. This increase in current in-migration will put downward pressure on current wages. Future local demand shocks are predicted using estimates from AR(2) processes of current local demand shocks.[5] The forecast horizon is taken as four years. Local demand shocks predicted for up to four years ahead are

[5]Current demand shocks are positive predictors of future demand shocks for all states.

Table 4.5: Average Annual Relative Demand Shocks

State	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	2005-2007
Alabama	-0.5	-0.1	0.9	0.7	-0.3	0.1
Arizona	0.0	0.7	-1.3	0.2	0.8	2.4
Arkansas	-0.6	-0.6	0.6	0.8	0.0	-0.2
California	0.1	0.5	-0.2	-1.2	0.1	0.3
Colorado	1.1	-0.3	-1.0	0.6	0.7	-0.3
Connecticut	0.3	1.5	-0.7	-1.2	-0.9	-0.5
Delaware	-1.1	0.4	0.5	0.3	0.7	0.4
Florida	-0.2	0.7	0.0	-0.2	0.6	1.9
Georgia	-0.5	0.8	0.5	1.2	0.8	0.2
Idaho	0.2	-1.6	-0.4	0.5	0.9	1.7
Illinois	-0.8	-0.7	-0.2	0.3	0.3	-0.1
Indiana	-1.2	-0.8	0.5	0.9	0.4	0.0
Iowa	-0.4	-1.2	-0.2	0.3	-0.2	-0.3
Kansas	0.2	-0.2	0.5	0.7	0.4	-0.7
Kentucky	-0.7	-0.5	0.7	0.7	0.4	-0.2
Louisiana	1.5	-1.3	-2.2	-0.8	-0.5	-1.2
Maine	-0.8	0.8	0.5	-0.4	0.9	-0.1
Maryland	-0.3	0.8	-0.1	-1.1	-0.2	0.0
Massachusetts	0.3	1.7	-1.1	-0.6	-0.2	-1.1
Michigan	-1.6	-0.7	-0.4	0.9	1.5	0.0
Minnesota	-0.2	-0.2	0.5	0.6	0.6	-0.2
Mississippi	-0.2	-0.9	-0.3	0.6	-0.1	-0.4
Missouri	-0.7	0.1	0.5	0.7	0.3	-0.2
Montana	0.7	-1.2	-0.9	0.0	-0.1	0.7
Nebraska	-0.3	-0.7	0.1	0.3	0.2	-0.5
Nevada	-0.3	-1.1	-0.5	1.2	2.4	4.0
New Hampshire	0.5	2.6	0.1	0.2	0.5	-0.6
New Jersey	-0.1	1.0	-0.7	-1.1	0.1	0.3
New Mexico	0.3	-0.1	0.0	0.3	0.1	0.7
New York	-0.4	0.7	-0.6	-1.3	-0.6	-0.5
North Carolina	-0.6	0.2	0.4	0.5	-0.1	0.0
North Dakota	1.4	-0.3	-0.8	-0.8	-2.2	-2.2
Ohio	-0.9	-0.5	0.1	0.7	0.8	-0.1
Oklahoma	2.1	-0.5	-1.3	-0.6	-1.0	-0.8
Oregon	-0.3	-0.8	0.5	1.2	0.3	0.6
Pennsylvania	-0.4	-0.1	-0.1	-0.5	-0.1	-0.2
Rhode Island	0.0	1.4	-0.5	-1.0	0.4	0.6
South Carolina	-0.2	0.4	0.8	0.4	-0.1	0.0
South Dakota	-0.5	-1.0	0.8	0.8	0.3	-0.4
Tennessee	-0.8	-0.3	0.6	0.9	0.3	0.0
Texas	1.6	0.3	-0.5	-0.2	-0.7	-1.0
Utah	-0.1	-0.7	0.0	1.5	0.3	0.6
Vermont	0.1	1.5	0.9	0.1	0.3	-0.6
Virginia	-0.2	1.0	0.6	-0.2	-0.2	-0.2
Washington	0.0	0.3	2.5	1.1	0.0	-0.6
West Virginia	0.5	-0.7	-0.4	0.1	-0.1	-0.4
Wisconsin	-0.6	-0.6	0.6	0.8	0.7	0.0
Wyoming	3.8	0.1	-1.1	-1.9	-2.1	0.1

then averaged to get the *predicted* average future local demand shocks. Main coefficients of interest here are that of current local demand shocks (β_ϵ), and those of its education interactions ($\beta_{\epsilon e}$).

Table 4.6 shows the estimation results for Equation (4.1) for 1980-1989, 1990-1999, and 2000-2007 periods. All regressions include current demand shocks, predicted average future local demand shocks, predicted employment growth rate, marital status, race, quartic experience, dummies for state, year, and 2-digit industry. The effect of current demand shock is positive in every column as expected. In column (1) of 1980-1989 period, we see that effect of demand shock on wages is large and statistically significant. One standard deviation decrease in current demand shock corresponds to a 4.3% decrease in wages. The coefficient for predicted employment growth rate is negative, but it is statistically insignificant. Predicted average future local demand shocks have the expected negative sign. Column (2) adds to column (1) interactions of local labour market variables and education dummies. Interaction term for college graduates shows that local demand shock effects on college graduate wages are significantly lower compared to high school graduate wages. A current one standard deviation decrease in local labour demand shock is estimated to be around 4.8% decrease in high school wages, while college wages are estimated to decrease by around 3% which is around 40% less than high school wage effects. Column (3) adds to column (2) experience interactions with local labour market variables. Coefficients for predicted employment growth rate are negative for college graduates and positive for high school graduates, but coefficient for high school graduates is statistically insignificant. This implies that predicted employment growth rate picks mostly supply changes during this period. Experience interactions are all negative, which contradicts with lower mobility of older workers. We expect that older workers are less able to or less willing to move out in response to negative shocks which would deepen adverse effects of these negative shocks on their wages. Estimated effects of one standard deviation decrease in current demand shocks on wages are 4.7% and 2.7% decrease in wages for high school and college graduates. Interactions for less than high school and some college education dummies with current demand shocks are statistically insignificant. The results for the 1980s also confirm previous evidence by Bound and Holzer (2000), who found that wages of high school graduates are affected more significantly by local demand disturbances compared to college graduates, who showed substantially higher inter-state mobility rates during the 1980s.

There is no evidence in the literature on how local demand shocks affected high school and college wages after the 1980s.[6] Wage effects of demand shocks are lower for the 1990s compared to the 1980s. Effect of one standard deviation decrease in local demand shocks is estimated to be around 2.6% and 1% decrease in wages for high school and college graduates, respectively. Difference in wage effects is larger compared to the 1980s. Local demand shock effects for other education groups are not statistically different from those for high school graduates.

For the 2000-2007 period, impact of local demand shocks on wages are smaller compared to the 1980s and 1990s. One standard deviation decrease in current local demand shock corresponds to around 1% decrease in high school wages. Moreover, the wage effects for college graduates are not statistically different from those for high school graduates, unlike earlier periods.

In sum, the 1980s and 1990s are characterized by deeper wage effects of local demand shocks for high school graduates compared to college graduates. These periods are also characterized by significant inter-state mobility differences between high school and college graduates. These differences in wage effects could be attributed to mobility differences between these education groups. Moreover, differences in wage effects disappear during the 2000s, which also corresponds to significantly lower differences in inter-state mobility

[6]Wozniak (2010) looks at medium-run wage effects of entry labour market conditions for high school and college graduates using U.S. Census 1980, 1990 and 2000 data. Here, we are looking at effects of current local market conditions rather than market conditions at the time individual enters labour force.

Table 4.6: Effect of Local Demand Shocks on Log Real Weekly Wages, 1980-2007

	1980-1989			1990-1999			2000-2007		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Current Demand Shock	0.043	0.048	0.047	0.022	0.026	0.026	0.010	0.010	0.010
	[0.003]**	[0.005]**	[0.005]**	[0.003]**	[0.004]**	[0.004]**	[0.003]**	[0.006]+	[0.006]+
Predicted Avg. Future Demand Shock	-0.007	-0.010	-0.010	-0.008	-0.008	-0.008	-0.001	-0.002	-0.002
	[0.001]**	[0.002]**	[0.002]**	[0.002]**	[0.003]**	[0.003]**	[0.001]	[0.002]	[0.002]
Predicted Employment Growth Rate	-0.018	0.021	0.023	-0.036	-0.035	-0.037	-0.022	-0.017	-0.018
	[0.016]	[0.025]	[0.025]	[0.015]*	[0.024]	[0.024]	[0.023]	[0.038]	[0.038]
Current Demand Shock X College		-0.018	-0.020		-0.017	-0.017		0.001	0.000
		[0.008]*	[0.008]**		[0.007]*	[0.007]*		[0.009]	[0.009]
Predicted Avg. Future Demand Shock X College		0.007	0.007		0.006	0.006		0.002	0.002
		[0.003]+	[0.003]*		[0.004]	[0.004]		[0.003]	[0.003]
Predicted Employment Growth Rate X College		-0.090	-0.096		0.060	0.061		-0.024	-0.027
		[0.043]*	[0.043]*		[0.039]	[0.039]		[0.059]	[0.059]
Current Demand Shock X Some College		0.002	-0.000		0.003	0.003		0.003	0.002
		[0.008]	[0.008]		[0.007]	[0.007]		[0.009]	[0.009]
Predicted Avg. Future Demand Shock X Some College		-0.002	-0.002		-0.003	-0.003		-0.001	-0.001
		[0.004]	[0.004]		[0.004]	[0.004]		[0.003]	[0.003]
Predicted Employment Growth Rate X Some College		-0.045	-0.051		-0.040	-0.042		-0.020	-0.022
		[0.044]	[0.044]		[0.037]	[0.037]		[0.058]	[0.058]
Current Demand Shock X Less Than HS		-0.006	0.000		0.003	0.002		-0.005	-0.004
		[0.009]	[0.009]		[0.008]	[0.008]		[0.010]	[0.010]
Predicted Avg. Future Demand Shock X Less Than HS		0.008	0.008		-0.009	-0.008		0.001	0.001
		[0.004]+	[0.004]+		[0.005]+	[0.005]		[0.004]	[0.004]
Predicted Employment Growth Rate X Less Than HS		-0.039	-0.026		-0.055	-0.044		0.062	0.062
		[0.050]	[0.050]		[0.048]	[0.048]		[0.076]	[0.076]
Current Demand Shock X Experience			-0.001			0.000			-0.000
			[0.000]**			[0.000]			[0.000]
Predicted Avg. Future Demand Shock X Experience			-0.000			-0.000			-0.000
			[0.000]			[0.000]			[0.000]
Predicted Employment Growth Rate X Experience			-0.001			-0.001			-0.001
			[0.000]**			[0.000]**			[0.000]**
R^2	0.42	0.42	0.42	0.42	0.42	0.42	0.40	0.40	0.40
N	220,963	220,963	220,963	227,140	227,140	227,140	289,938	289,938	289,938

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$

In columns 3 for each period, coefficients reported for current demand shock are estimated effects at mean experience level within that period. Current demand shock variable is standardized to have a mean 0 and a standard deviation of 1 for each year. Each regression includes dummies for state, year, 2-digit industry, marital status and race, and quartic experience. Standard errors are in parantheses.

rates between college and high school graduates.

4.5 Conclusion

It has been documented that less educated workers experienced significant decreases in their earnings during the 1980s. On the other hand, the earnings of those with higher education increased during this period. In the late 1980s, the earnings of high-educated showed a somewhat flat pattern, while the earnings of low-educated continued to decline during this period. These contributed to a rapid increase in the overall wage inequality during the 1980s. Some studies attempted to understand the reason for this continuing deterioration of wages for the low-educated. Apart from national level demand and supply explanations, researchers also used local variations in demand shifts to understand the determinants of wages of high and low-educated labour. Two of the important studies in this area are Topel (1986) and Bound and Holzer (2000), which investigated wage changes in the periods 1977-1980 and 1980-1990, respectively. Both of these studies found that limited supply adjustments in response to local demand shocks could explain some of the increase in wage gap during these periods, i.e. high school graduates' earnings deteriorated more following a negative demand shock due to their relatively low ability of shifting supply from one locale to another, where conditions are better or less severe.

In this chapter, I explored the effects of local demand shocks on wage levels of high school and college graduates for the period 1980-2007. Three periods are considered in the analysis: 1980-1989, 1990-1999 and 2000-2007. The 1980s and 1990s are characterized by fast increases in college-high school wage gap (faster in the 1980s), while the 2000s show slower increases in the wage gap compared to the 1980s and 1990s.[7] An initial de-

[7] Average annual change in college-high school wage gap is 1.4%, 1% and 0.3% during 1980-1989, 1990-1999 and 2000-2007, respectively.

scriptive analysis showed that fluctuations in wages are greater for high school graduates compared to college graduates, especially during the 1980s. Fluctuations in high school wages decrease after the 1980s, and are also accompanied by converging mobility rates between high school and college graduates. There is an overall decline in inter-state mobility rates from 1980s to 2000s for both education groups, but differences in mobility rates decline over time due to larger declines in college mobility rates.

The main contribution of this chapter is to show that convergence in mobility rates for college and high school labour is also accompanied by converging wage effects of local demand shocks. This confirms the importance of labour supply adjustments across local labour markets for wage changes. I show that local demand shocks have deeper effects for high school graduates in the 1980s and 1990s, while the 2000s do not show any difference in wage effects.[8] The disappearance of differences in wage effects of local demand shocks for high school and college graduates in the 2000s corresponds to a period of converging inter-state mobility rates for the two education groups compared to the 1980s and 1990s. The implicit assumption here is that local shocks are skill-neutral, and college and high school graduates compete in the same market, and therefore they are substitutable with each other, which is supported by the findings in the third chapter.[9] Given that these two types of labour are fairly substitutable, the more dramatic decrease in wage effects for high school graduates, and therefore convergence in wage effects of local demand shocks by education could have been facilitated by declining differences in mobility between college graduates and high school graduates.

There could be other reasons for the equalization of wage effects between the two education groups: (i) Local demand shocks could be non-neutral. It is shown that mobility

[8]This also confirms findings from Bound and Holzer (2000) which looked at 10-year change from 1980 to 1990 using U.S. Census data at the MSA level.

[9]I find that elasticity of substitution between high school and college graduates change between 1.8 and 2.4 across Census regions in the U.S. Although, differences in elasticities are not statistically significant at 10% level.

declined for both education groups (more dramatically for college graduates), but the wage effects of shocks did not increase. As mentioned above, local shocks are assumed to be skill-neutral in the sense that they are not indicators of separate demand shocks for high school and college graduates. However, there could be biases towards low-skilled workers in *predicted* local demand shocks used here, which could produce these declining wage effects for college graduates. (ii) There are differences in responsiveness to local demand changes within the less-skilled market, between immigrants and natives. Cadena and Kovak (2013) find that less-skilled native men could be partially insulated from adverse effects of demand declines due to high mobility of Mexican workers. Overall, the Mexican population ratio increased from 2.5% in 1994 to 4% in 2007.[10] Therefore, declining wage effects for high school graduates might also be related to the increasing share of Mexican workers within the less-skilled labour force. Moreover, slower decreases in high school graduate mobility compared to college graduates could also be due to this increasing share of Mexican workers, who reduce the need for native high school graduates to move as much as they had to in the earlier years.

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Chapter 5

Conclusion

This thesis examines movements in college wage premium and college-high school skill price differentials at the national and local levels, and implications of local population adjustments for changes in college wage premium in the U.S. The second chapter aims to resolve some of the puzzling results from the standard supply-demand model of college-high school relative skill prices as implemented in the literature. Noting that the standard proxies used for relative skill prices and supplies (composition adjusted relative wages and total annual hours) do not account for changes in relative average skill levels, it re-estimates the canonical model using alternative series for relative prices and supplies, which are estimated by making a careful distinction between changes in wages and prices (i.e. accounting for changes in skill levels). The results imply that poor performance of the canonical model (after the 1990s) is a result of mismeasurement of relative skill prices and supplies. The elasticity of substitution between college and high school labour is higher than what is suggested by the standard approach. Moroever, SBTC has a much smaller role, and changes in relative skill levels seem to be an important factor for the evolution of college wage premium.

The third chapter examines the implications of the canonical model at the Census regional level using the more general approach in the second chapter. The results indicate that implications of the standard approach for regional differences in relative demand for college labour and elasticities of substitution between college and high school labour do not hold using the alternative price and quantity series. Differences in movements in relative skill prices is mainly driven by differences in relative skill supply changes across regions.

The fourth chapter estimates and compares the short-term effects of local demand shocks on wages during the 1980s, 1990s and 2000s for the high school and college graduates, and relates these effects to changes in mobility over time. The results show that the 1980s is characterized by significant wage effects of local demand shocks for both groups, but deeper wage effects for high school graduates. Moreover, differences in wage effects persist in the 1990s, but disappear in the 2000s which also corresponds to period of converging annual inter-state mobility rates between these groups, which shows the importance of labour reallocation across markets for wages.

Appendix A

Measurement Error in Relative Skill Prices

A.1 Measurement Error in Relative Skill Prices

Suppose the relative price in BR is measured with error such that:

$$ln\omega^m = ln\omega + \epsilon$$

Since the relative skill quantity, $ln(H/L)$, is obtained by dividing the total wage payment to H relative to the total wage payment to L by the relative price, the log relative skill quantity will also be measured with the same error, but opposite in sign:

$$ln(H/L)^m = ln(H/L) - \epsilon$$

This implies that estimating equation (5) is equivalent to estimating the model:

$$ln\omega^m = \alpha + \beta ln(H/L)^m + (1 + \beta)\epsilon$$

where $\alpha = \frac{\sigma-1}{\sigma} ln(A_H/A_L)$, $\beta = -\frac{1}{\sigma}$ and $(1+\beta)\epsilon$ is (part of) the error term. If $\sigma = 1$, using the measured variables in place of the true variables estimates the same parameters. For other values of σ, if ϵ is classical measurement error, $plim\hat{\beta}$ is a weighted average of the true β and -1:

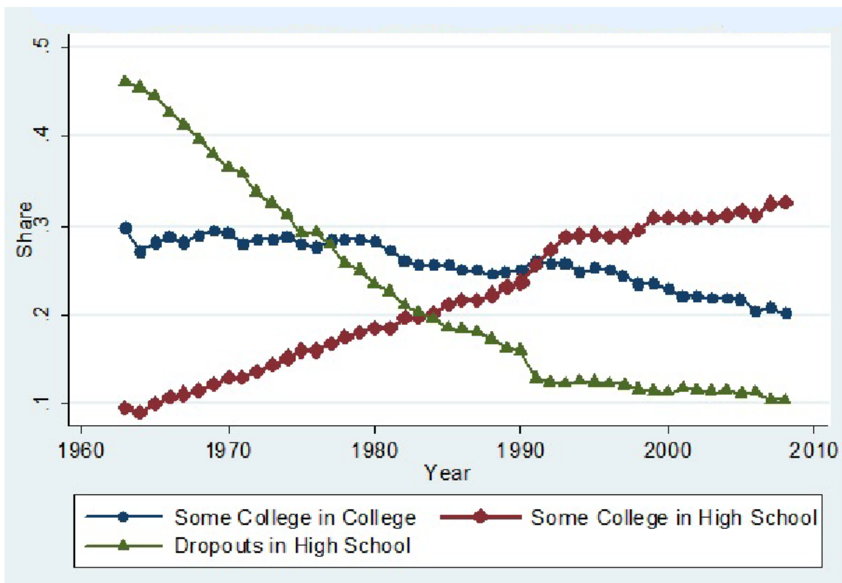
$$plim\hat{\beta} = \theta\beta + (1-\theta)(-1)$$

where $\theta = \frac{Var(ln(H/L))}{Var(ln(H/L))+Var(\epsilon)}$. As $Var(\epsilon) \rightarrow 0$, $plim\hat{\beta} \rightarrow \beta$. So for any value of $\sigma > 1$ the bias moves the estimate towards 1.

A.2 Components of the Composition Adjusted Skill Types

The shares of the components of the composition adjusted "high school graduate" skill and "college graduate" skill changed over time. Figure A.1 shows the dramatic decline in the share of dropouts in the high school group and increase in the share of some college. Since within the high school aggregate the dropouts are presumably least substitutable for college graduates and some college are the most substitutable, these patterns suggest an increase in the elasticity of substitution over time between the aggregates.

Figure A.1: Component Shares of the Composition-Adjusted Aggregates



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