Market Power, Globalization and Labor Market Trends

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Abstract

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This dissertation studies various economic forces that potentially shape the recent labor market trends. In the first chapter, I develop a general equilibrium model which incorporates the job polarization mechanism into monopolistic competition to explore the role of the rising market power on a set of post-2000 US labor market trends, including the stagnation of wage growth, the slowdown of wage polarization, the decline of aggregate labor share and the distinct labor share trends across routine and non-routine occupations. Comparative static analysis suggests rising market power qualitatively contributes to these trends. The calibrated model can quantitatively account for the trends with the magnitude of increase in markups close to the higher end of range in the literature. Empirically, I find that increases in industry concentration are associated with declines in aggregate labor share, declines in labor share across non-routine and routine occupations, and stagnation of growth in wages per efficiency unit of labor across both occupational groups.

In the second chapter, I employ a dynamic general equilibrium model with two types of labor to jointly assess the effects of consumption tariff reduction, materials tariff reduction and financial liberalization on the skill premium, based on the calibration to a generic debtor economy. The simulation results highlight the sharply contrasting effects from these various forms of globalization and the diverse mechanisms involved as the economy adjusts over time. In particular, while both forms of the tariffs reduction reduces the skill premium

upon impact, the reduction in materials tariff increases the skill premium over time whereas the reduction in consumption tariff further reduces the skill premium along the transitional path due to their opposing effects on the growth of capital stock. In contrast, financial liberalization increases the skill premium on impact while the transitional dynamics of the skill premium later on exhibits a hump-shaped evolution driven by the two countervailing forces of growing capital stock and rising skilled labor supply.

The third chapter contains several extensions to the second chapter, which includes dissecting the mechanisms driving the dynamics of the skill premium, an extensive sensitivity analysis on the key structural parameters, considerations of alternative form of production function and the calibration to a creditor economy. Although the qualitative nature of the responses to the two forms of tariffs reduction and financial liberalization in the benchmark model are fairly robust with respect to variations in key structural parameters, the simulation indicate that the impact effect of material tariff reduction changes dramatically if the imported raw materials are more complementary with skilled labor than they are with unskilled labor. It also leads to very different impact effects of the tariffs reduction and long-run effects of financial liberalization if the external financial position of the economy changes from a debtor to a creditor. The results thus call for the considerations into the composition of the imported raw materials and the external financial position of the economy when evaluating the effects of globalization on the skill premium over time.

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Chapter 1

MARKET POWER AND LABOR MARKET TRENDS[1]

1.1 Introduction

Thriving competition is an essential component of a well-functioning market economy and changes in the degree of competition have vital implications for resource allocation. Empirical investigations have found a broad-based secular rise in market power in the United States at least as far back as 2000 (Barkai (2016), De Loecker and Eeckhout (2017), Hall (2018), Covarrubias et al. (2019), and others). In this paper, I develop a general equilibrium model to demonstrate how a set of post-2000 labor market trends in the United States, including the stagnation of wage growth, the slowdown of wage polarization, the decline of aggregate labor share and the distinct labor share trends across routine and non-routine occupations, can be both qualitatively and quantitatively accounted for by the rising market power. Exploiting cross-industry variation, I find suggestive evidence supporting most of the testable hypotheses.

I start by presenting a set of post-2000 labor market trends in the United States. Using micro-level data collected from Annual Social and Economic Supplement (ASEC) of the Current Population Survey (CPS) I show that wage polarization-the comparatively high growth of wage in non-routine occupations relative to routine occupations-has slowed down and wage growth across both occupational groups has stagnated since 2000, even after controlling for the education level and demographic composition. Meanwhile, routine labor share has continued downward trend whereas non-routine labor share has turned to decline from the previous rise, which results in the dramatic post-2000 decline of aggregate labor share.

[1]Partial support for this research came from a Eunice Kennedy Shriver National Institute of Child Health and Human Development research infrastructure grant, P2C HD042828, to the Center for Studies in Demography & Ecology at the University of Washington.

I then develop a general equilibrium model that relates the set of labor market trends to the rising market power. Monopolistically competitive firms differentiate an intermediate input into a continuum of final goods and sell them at a constant markup over marginal cost. A perfectly competitive intermediate good sector produces the intermediate input with capital, non-routine task labor and routine task labor using a constant elasticity of substitution (CES) technology and, following the job polarization literature, the technology features non-routine task labor being more complementary to capital than routine task labor (capital-task complementarity, henceforth).

Increases in markups of the final goods producing firms reduce the real price (in units of the final goods composites) of the intermediate input, and thus impose downward adjustment pressure on both the output and demand for all factors of production in the intermediate good sector. Drop in demand, in particular, slows down the accumulation of capital, reducing the capital-labor ratio. The reduced capital-labor ratio decreases the marginal product of labor and, together with the drop in the real price of intermediate good, reduces the real wage for both tasks. Moreover, the lower capital-labor ratio disproportionately hurts the non-routine task labor through the capital-task complementarity effect, thus slows down the wage polarization and induces more labor to work in the routine task, reducing the wage-bill ratio of non-routine to routine task. Changes in capital-labor ratio and non-routine to routine labor ratio affect the shares of each factor in business costs for nonunitary elasticities of substitution. Additionally, rises in markups increase the profit share and reduce the business cost relative to income, which tends to reduce the labor share of income across both tasks.

To quantitatively evaluate the model performance of the variables of interest for the post-2000 period, I calibrate the initial steady state of the model to match the level of variables of interest measured at the start of the sample period (1996-2000). Then I compare variables of interest measured at the end of sample period (2011-2015) with those generated at a new steady state that differs from the initial one due to the observed changes in the exogenous variables, including markups, the investment-specific technology and real risk-free interest rate, which are used to capture the changes of the macroeconomic environment. Counterfactual analysis are used to quantify separately the role of each individual exogenous variable.

The model generates a decline in routine labor share, increases in non-routine wage premium and relative labor share between non-routine and routine occupations by magnitudes close to the observed changes in the data. It over predicts the skill prices a bit and doesn't generate enough decline in aggregate labor share and non-routine labor share, which suggests other channels not incorporated in this model may be at work and/or the estimated increase in markups could be downward biased. Given the large range of magnitude of increase in markups estimated in the literature, I then ask what would be the end value of markups that could fully account for the observed decline of the aggregate labor share and under this value how well this model could capture the changes of other variables of interest. It turns out the required magnitude of increase in markups would be 19 percentage points, which is close to the upper end of range estimated in the literature. Under this higher end value of markups, the model produces changes in most variables of interest by magnitudes very close to those observed in the data. Moreover, the counterfactual analysis indicates that the increase in markups has a quantitatively large effect on most of the variables of interest.

Lastly, I exploit the cross-industry variation in market power and variables of interest and find suggestive evidence for several testable hypotheses derived from the model. Supported by the findings in Covarrubias et al. (2019), I use the change in market concentration as a proxy to the change in market power at the industry level for the post-2000 period. The results show that increases in industry concentration are associated with declines in aggregate labor share, declines in labor share across non-routine and routine occupations, and stagnation of growth in wages per efficiency unit of labor across both occupational groups.

1.2 Related Literature

There is a growing literature documenting a broad-based secular rise in market power as reviewed in Basu (2019), and it triggers a round of research discussing the macroeconomic implications of the rising market power. Barkai (2016) ties the decline in competition and increase in markups to the decline in aggregate labor share. De Loecker and Eeckhout (2017) discusses the implications of rising market power on the decrease in labor market dynamism as well as the declining aggregate labor and capital share. Gutiérrez and Philippon (2017) relates the decreasing competition to the post-2000 weak investment relative to fundamentals. Farhi and Gourio (2018) links rising market power to the stability of the return to private capital despite of the decreasing risk-free rate, the moderate increase in stock market valuation ratios and weak investment. In a similar spirit, Eggertsson et al. (2018) also ties rising market power, along with the decline of real interest rate, to a set of macro-finance trends, which include the decline of aggregate labor share, the increase in financial wealth-to-output ratio, the increase in measured Tobin's Q and a divergence between the marginal and the average return on capital. My work, which provides a unified explanation based on rising market power for a set of post-2000 labor market trends, naturally contributes to this strand of literature.

My work also relates to the large job polarization literature (Autor et al. (2003), Autor et al. (2006), Autor et al. (2008), Autor and Dorn (2013), and others), which studies the comparatively high growth in employment and wages for non-routine (low and high skilled) occupations relative to routine (middle skilled) occupations. Much discussion of the job polarization literature has centered around the role of technological change (or automation). Autor et al. (2003) and subsequent papers in this literature suggest that the progress in automation reduces the price of machines capable of performing routine tasks and substitutes for labor in such occupations. While labor in non-routine occupations is more complementary to machines in production, the reduced price of machines raises the demand for the non-routine labor. However, very recent studies which examine the quantitative effect of the technological change on the job polarization process find it unsatisfactory to account for the dynamics over time. vom Lehn (2019) finds the observed investment-specific technology growth can not simultaneously reconcile the rapid polarization in the 1980s and 1990s with the much slower polarization since the 2000s. Cortes et al. (2017) also points out that the observed technological change can only account for a relatively small portion of the decline of the routine employment and the associated rise in non-routine manual employment and non-employment. My work relates the rising market power to the post-2000 slowdown of the wage polarization, potentially enriching the understanding of the driving forces of the dynamics of job polarization.

Finally, my paper relates to the expanding literature on the decline in the labor share of income (Elsby et al. (2013),Karabarbounis and Neiman (2014), Rognlie (2016), Autor et al. (2017), Acemoglu and Restrepo (2018), Eden and Gaggl (2018), and others). As already discussed, Barkai (2016), De Loecker and Eeckhout (2017) and Eggertsson et al. (2018) have tied the increase in markups to the decline in aggregate labor share, but none of them has looked into how market power may have differential effect on the labor shares across different occupations. My results show that the rising market power could reduce the relative labor share of non-routine occupations to routine occupations.

1.3 Empirical Facts

This section presents the macroeconomic trends of interest in this study. I focus on the corporate sector in the United States to exclude the role of housing and avoid the issue with the imputation of proprietor's income. These trends are summarised as four facts.

Fact 1: Market power has been rising. I follow the methodology used in Barkai (2016) to construct the economic profit share using macro-level data and impute markups from it under the assumption of constant return to scale of production.[2]

Figure 1.1(a) shows the factor shares trends. Labor share exhibits a decline after 2000. Capital share is stable or has decreased moderately since 1980. Profit share shows a mild increase since 1980 and a sharp rise after 2000. The imputed markups mirrors the trend of the profit share and shows a dramatic increase right after 2000 as shown in Figure 1.1(b).

De Loecker and Eeckhout (2017) and Hall (2018) use micro-level data and different

[2]See Appendix A.1 for the details of data source and data constructions.

methodologies to estimate markups and also find an upward trend, though the start of the trend and magnitude of increase differ in general. The sharp rise of markups after 2000 shown here is consistent with the findings in Covarrubias et al. (2019), which studies the joint evolution of productivity, prices, markups and market concentration and concludes that the year 2000 is the turning point where the decline in competition and the rise in market power started.

Fact 2: Wage polarization has slowed down. The job polarization literature (e.g. Autor et al. (2003), Autor et al. (2006), Autor et al. (2008), Autor and Dorn (2013)) has well documented the wage polarization-the comparatively high growth of wage in non-routine occupations relative to routine occupations-since the 1980s in the United States.[3] The sample period in the literature usually covers up to the early 2000. To look at the recent wage polarization trend, I collect micro-level data to include the sample up to the year 2015 from ASEC of the CPS available through IPUMS (Flood et al. (2015)).[4] I construct the consistent occupation codes using crosswalk files provided by Autor and Dorn (2013) and vom Lehn (2018) and group all occupations into routine and non-routine occupations based on Autor and Dorn (2013).[5] Farm sector, government sector and private household sector are removed from the CPS sample for the comparability with the corporate sector.

Figure 1.2 shows the non-routine raw average wage premium (i.e. the ratio of the average real wage of non-routine occupations to routine occupations). There is a clear upward trend since the early 1980s which reflects the wage polarization, but the rise slows down after 2000. Both changes in the education level and demographic composition and changes in the skill

[3]The non-routine occupations include both non-routine abstract occupations which require intuition, judgement and creativity, and non-routine manual occupations which involve physical exertion or interpersonal skills. Routine occupations typically follows strict, pre-specified procedure and are highly repetitive. By the very nature of the routine occupations, these jobs are more susceptible to automation.

[4]To adjust the top-coded wage and salary income in the CPS, I follow vom Lehn (2018) to use the cell means procedure of Larrimore et al. (2008) and fit a Pareto distribution to the upper tail of the income distribution to correct for the internal top coding of the CPS.

[5]Autor and Dorn (2013) does not provide time-consistent coverage for the most recent Census occupational code revision which is implemented in the CPS in 2010. vom Lehn (2018) uses crosswalks provided by the Census and generates a consistent mapping for the years after the most recent revision.

prices (i.e. wages per efficiency unit of labor) could contribute to the trend change in raw average wage premium. To isolate out the changes in the relative skill price, similar to vom Lehn (2019), I run a Mincerian regression each year, t, to control for the education and demographic factors' changes:

$$lnw_{i,t} = \beta_{0,t} + \beta_{1,t} NR_{i,t} + \beta_{2,t} X_{i,t} + \epsilon_{i,t} \quad for\ t \in \{1979, 2015\} \tag{1.1}$$

where $lnw_{i,t}$ is the log wage for individual i in year t. $NR_{i,t}$ is a dummy variable indicating that individual i works in a non-routine occupation in year t. $X_{i,t}$ includes age, age square, indicators for sex, race, education and interaction of indicator for education and age. Regression is weighted by sampling weights. The skill prices for routine and non-routine occupations in year t are constructed as $w_{rt} = exp(\hat{\beta}_{0,t})$ and $w_{nt} = exp(\hat{\beta}_{0,t} + \hat{\beta}_{1,t})$ respectively. The non-routine wage premium (i.e. the relative skill price, $\frac{w_{nt}}{w_{rt}}$) is thus $exp(\hat{\beta}_{1,t})$.

Figure 1.3 plots the 5-year moving average of non-routine wage premium. The slowdown of the growth is less obvious than that of the raw average wage premium, indicating changes in education level and demographic factors partially account for the trend change. Nevertheless, the post-2000 increase in non-routine wage premium is still slower than the pre-2000 period-it increases by 9.04 percentage points over the period 1984-1999 and only by 5.25 percentage points over the period 2000-2015.[6]

Fact 3: Wage growth has slowed down. Figure 1.4 shows the raw average wage and skill prices by routine and non-routine occupations. There is a visible slowdown of wage growth around 2000 across both occupational groups and in terms of both raw average wage and skill prices. Eden and Gaggl (2018) also constructs the skill prices by non-routine and routine occupations with the same data source but uses a different methodology-they decomposes the sample into demographic cells and use Fisher's ideal formula to construct chained quantity index of labor, then construct the implicit price deflator as the skill price. Their results also

[6] As mentioned in the section of Related Literature, the slowdown of job polarization since the 2000s is also noted by vom Lehn (2019).

show an apparent slowdown of the growth in skill prices right after 2000.[7]

Fact 4: Labor shares across occupations exhibit distinct trends. The aggregate labor share of income of the corporate sector in the United States started to decline since 2000, as depicted in Figure 1.5. I further decompose the aggregate labor share into routine labor share and non-routine labor share based on the earnings ratio of the two occupational groups at each year using data on wage and salary income from the ASEC of CPS.[8] The pre-2000 stability of the aggregate labor share masks the underlying different labor share trends across routine and non-routine occupations-routine labor share has been declining since the start of the sample period and this is offset by the rise in non-routine labor share, leading to the stability on aggregate until 2000. While there is no trend change in the routine labor share, the non-routine labor share turns to decline from the previous rise after 2000. The sharp trend change in non-routine labor share breaks the stability on aggregate and results in the dramatic post-2000 decline in aggregate labor share.[9] The distinct labor share trends by occupations are also confirmed by the empirical findings in vom Lehn (2018) and Eden and Gaggl (2018).[10]

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[7]See Panel B1 and B2 of Fig. F.16 in Eden and Gaggl (2018) for their results. The non-routine wage premium constructed using the relative implicit price deflator in their paper also shows a slowdown of increase after 2000.

[8]Wage and salary income in the ASEC of CPS data indicates each respondent's total pre-tax wage and salary income-that is, money received as an employee and amounts are expressed as they were reported to the interviewer. It excludes supplements to wage and salary income, while in NIPA the compensation of employees includes wage and salary income, whether paid in cash or in kind, and supplements to wage and salary income. See Chapter 10 of the NIPA Handbook: `https://www.bea.gov/sites/default/files/methodologies/nipa-handbook-all-chapters.pdf` for the definition of compensation of employees in the national account.

[9]The fact that the post-2000 decline in labor share is driven by the sharp trend change in non-routine labor share is an evidence against the explanation for the decline in labor share since 2000 based on automation; by the very nature of the non-routine occupations, these are the kind of jobs less prone to being automated comparing with routine occupations.

[10]See Fig.2 in vom Lehn (2018) and Panel A of Fig.1 in Eden and Gaggl (2018) for their results.

1.4 Model

In this section, I develop a general equilibrium model that relates the labor market trends documented above to the market power measured by markups as well as to other macroeconomic variables, such as the relative price of investment goods and real risk-free interest rate. The model features the elements that have been traditionally considered by the job polarization literature, which includes the CES aggregate production function with non-routine task labor more complementary to capital than routine task labor and endogenous task choice of labor. The difference is that I incorporate these elements into a monopolistic competition (instead of perfect competition) framework. This allows me to study the *implications* of the variation of market power on the labor market.

The horizon is infinite and there is no uncertainty. All agents in the economy have perfect foresight about the evolution of all exogenous driving forces. The setup of the market structure is similar to that in Eggertsson et al. (2018) with the final goods sector being monopolistically competitive and the intermediate good sector being perfectly competitive.

1.4.1 Final Goods Sector

There is a unit measure of monopolistically competitive final goods firms, indexed by $i \in [0, 1]$, that differentiate an intermediate good and sell it to the household. The final goods composite Y_t, assembled by the households and used for both consumption and investment, is a CES aggregate of these differentiated final goods $y_t^f(i)$:

$$Y_t = [\int_0^1 y_t^f(i)^{\frac{\Lambda_t - 1}{\Lambda_t}} di]^{\frac{\Lambda_t}{\Lambda_t - 1}} \tag{1.2}$$

where $\Lambda_t > 1$ denotes the elasticity of substitution between final goods varieties.

Denote the price of final good variety i as $p_t(i)$. Cost minimization of the households implies the nominal price index of the final goods composite is:

$$P_t = [\int_0^1 p_t(i)^{1-\Lambda_t} di]^{\frac{1}{1-\Lambda_t}} \tag{1.3}$$

and the demand for final good variety i is:

$$y_t^f(i) = Y_t(\frac{p_t(i)}{P_t})^{-\Lambda_t} \tag{1.4}$$

Each final goods producer purchases the intermediate good y_t^m from perfectly competitive intermediate good firms and differentiate it according to a linear production technology: $y_t^f = y_t^m$. Final goods firm i takes the intermediate good price p_t^{int}, the the price index of the final goods composite P_t and the aggregate demand for the final goods composite Y_t as given, but chooses price $p_t(i)$ and output $y_t^f(i)$ to maximize profits, subject to the production technology and demand constraints:

$$\max_{\{p_t(i), y_t^f(i)\}} p_t(i) y_t^f(i) - p_t^{int} y_t^f(i)$$

$$s.t. \quad y_t^f(i) = Y_t(\frac{p_t(i)}{P_t})^{-\Lambda_t}$$

The optimality condition implies that:

$$p_t(i) = \frac{\Lambda_t}{\Lambda_t - 1} p_t^{int} = \mu_t p_t^{int} \tag{1.5}$$

where $\mu_t \equiv \frac{\Lambda_t}{\Lambda_t - 1}$ is the optimal markup of firm i. Equation (1.3) and (1.5) imply $p_t(i) = P_t$ and $p_t^{int} = \frac{1}{\mu_t} P_t$. Equation (1.4) further indicates $y_t^f(i) = Y_t$. The aggregate profits of final goods firms are thus given by:

$$\Pi_t = \int_0^1 [p_t^f(i) y_t^f(i) - p_t^{int} y_t^f(i)] di = \frac{\mu_t - 1}{\mu_t} P_t Y_t \tag{1.6}$$

Profits earned by the final goods firms are distributed to the shareholders in the form of dividends:

$$d_t^f = \Pi_t \tag{1.7}$$

For simplicity of the notation, normalize $P_t = 1$, which implies that the numeraire is the final goods composite.

1.4.2 Intermediate Good Sector

Intermediate good sector is perfectly competitive. The representative firm produces intermediate good Y_t^m that is used by the final goods firms as input. Intermediate output is produced by a constant return to scale technology in three factors of input - capital, routine task labor and non-routine task labor, according to the following aggregate production function (which takes similar form to that in Krusell et al. (2000)):

$$Y_t^m = [\Phi_1[\Phi_2 K_t^\rho + (1-\Phi_2)L_{nt}^\rho]^{\frac{1}{\rho}\sigma} + (1-\Phi_1){L_{rt}}^\sigma]^{\frac{1}{\sigma}} \tag{1.8}$$

where L_{jt} is the amount of labor in efficiency unit employed in task j, $j \in \{r, n\}$ with r denoted as routine task and n denoted as non-routine task, and K_t is capital in efficiency unit. σ and ρ ($\sigma, \rho < 1$) govern the elasticity of substitution between capital and labor in different tasks. In particular, $\gamma_n \equiv \frac{1}{1-\rho}$ is the elasticity of substitution between capital and non-routine labor and $\gamma_r \equiv \frac{1}{1-\sigma}$ is the elasticity of substitution between routine labor and the composite product of capital and non-routine labor. I follow the standard hypothesis in the job polarization literature to assume that non-routine labor is more complementary with capital than is routine labor (i.e. $\gamma_n < \gamma_r$ or $\sigma > \rho$).

The representative intermediate good firm rents capital at rate r_t and rents labor doing task j at skill price w_{jt} from the household, and sells its output at price $p_t^{int} = \frac{1}{\mu_t}$ to the final goods firms. The profit maximization problem of the representative firm is:

$$\max_{\{K_t, L_{rt}, L_{nt}\}} \frac{1}{\mu_t} Y_t^m - W_{rt}L_{rt} - W_{nt}L_{nt} - r_t K_t$$

The first-order conditions for the representative firm's problem are:

$$W_{nt} = \frac{1}{\mu_t}\frac{\partial Y_t^m}{\partial L_{nt}} = \frac{1}{\mu_t}\Phi_1(1-\Phi_2)(Y_t^m)^{1-\sigma}(\Phi_2 K_t^\rho + (1-\Phi_2)L_{nt}^\rho)^{\frac{\sigma-\rho}{\rho}} L_{nt}^{\rho-1} \tag{1.9}$$

$$W_{rt} = \frac{1}{\mu_t}\frac{\partial Y_t^m}{\partial L_{rt}} = \frac{1}{\mu_t}(1-\Phi_1)(Y_t^m)^{1-\sigma} L_{rt}^{\sigma-1} \tag{1.10}$$

$$r_t = \frac{1}{\mu_t}\frac{\partial Y_t^m}{\partial K_t} = \frac{1}{\mu_t}\Phi_1\Phi_2(Y_t^m)^{1-\sigma}(\Phi_2 K_t^\rho + (1-\Phi_2)L_{nt}^\rho)^{\frac{\sigma-\rho}{\rho}} K_t^{\rho-1} \tag{1.11}$$

The factors' prices are equal to their marginal revenue product (i.e. the marginal product times the price of the intermediate good, $\frac{1}{\mu_t}$).

The first-order conditions of the representative intermediate good firm's problem give some intuitions about how changes in factor quantities affect the non-routine wage premium, $\frac{W_{nt}}{W_{rt}}$. To see this, dividing equation (1.9) by equation (1.10), I obtain the following expression for the non-routine wage premium:

$$\frac{W_{nt}}{W_{rt}} = \frac{\Phi_1(1-\Phi_2)}{1-\Phi_1} \underbrace{(\Phi_2(\frac{K_t}{L_{nt}})^\rho + (1-\Phi_2))^{\frac{\sigma-\rho}{\rho}}}_{\text{capital-task complementarity effect}} \overbrace{(\frac{L_{rt}}{L_{nt}})^{1-\sigma}}^{\text{relative quantity effect}}$$

where there are two components that affect the non-routine wage premium. The first component is the capital-task complementarity effect, $(\Phi_2(\frac{K_t}{L_{nt}})^\rho + (1-\Phi_2))^{\frac{\sigma-\rho}{\rho}}$. Under the assumption that non-routine task labor is more complementary with capital than is routine task labor (i.e. $\sigma > \rho$), an increase in capital tends to increase the non-routine wage premium, as it drives up the relative demand for non-routine task labor. The second component is the relative quantity effect, $(\frac{L_{rt}}{L_{nt}})^{1-\sigma}$. An increase in the routine task labor in efficiency units relative to non-routine task labor in efficiency units tends to increase the non-routine wage premium as $\sigma < 1$.

1.4.3 Household

A representative household has a unit measure of members, indexed by identifier $\tau \in [0,1]$, with the vector of efficiencies $(h(\tau), \xi)$ for non-routine task and routine task respectively. It is convenient to choose a functional form for $h(\tau)$ to permit analytic solutions; following Beaudry et al. (2016), I assume $h(\tau) = \tau^{-\frac{1}{2}}$. The household purchases final goods from the final goods firms and assembles them into final goods composite which are used for both consumption and investment. One unit of the consumption good is identical to one unit of the final goods composite. The household has free access to an investment specific technology which converts one unit of final goods composite into q_t efficiency units of investment good. Arbitrage thus implies that $\frac{1}{q_t}$ is the relative price of investment good to consumption good. Increase in q_t reflects improvement in the investment-specific technology which lowers the relative price of investment good. Investment good is used to augment capital stock which is rented to the intermediate good firm at r_t. Members of the household are allocated to non-routine task and routine task at skill prices W_{nt} and W_{rt} respectively. The household owns all shares of the portfolio of the securities of the final goods firms, which gives the rights to all future dividends d_t^f of these firms.

The representative household's problem is:

$$\max_{\{C_t, I_t, K_{t+1}, \bar{\tau}_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \log(C_t)$$

$$s.t.\ C_t + \frac{1}{q_t} I_t \leq W_{nt} \int_0^{\bar{\tau}_t} h(\tau) d\tau + W_{rt} \int_{\bar{\tau}_t}^1 \xi d\tau + r_t K_t + d_t^f$$

$$K_{t+1} = I_t + (1-\delta) K_t \tag{1.12}$$

K_0 is given. $\bar{\tau}_t$ is the cut-off value of the identifier: members with an identifier below $\bar{\tau}_t$ (ranked as relatively more efficent in terms of doing non-routine task) will be assigned to the non-routine task; those with an identifier above $\bar{\tau}_t$ will be assigned to the routine task.

The first-order condition with respect to $\bar{\tau}_t$ is:

$$W_{nt}h(\bar{\tau}_t) - W_{rt}\xi = 0 \Rightarrow \frac{W_{nt}}{W_{rt}} = \frac{\xi}{\bar{\tau}_t^{-\frac{1}{2}}} = \xi(\bar{\tau}_t)^{\frac{1}{2}} \tag{1.13}$$

Equation (1.13) relates the the cut-off value identifier, $\bar{\tau}_t$, to the non-routine wage premium, $\frac{W_{nt}}{W_{rt}}$. In particular, an increase in the non-routine wage premium induces more members to be assigned in the non-routine task and less in the routine task, as reflected by a higher $\bar{\tau}_t$.

The first-order condition with respect to capital is:

$$r_{t+1} = \frac{1}{q_t}\left(\frac{C_{t+1}}{C_t\beta} - \frac{1-\delta}{\frac{q_{t+1}}{q_t}}\right) \tag{1.14}$$

This condition expresses rental rate of capital, r_{t+1}, as a function of the relative price of investment good, $\frac{1}{q_t}$, the inverse of the consumption based discount factor (or, equivalently the gross real interest rate of a riskless bond denominated in units of consumption good), $\frac{C_{t+1}}{C_t\beta}$, and capital gains from undepreciated capital, $\frac{1-\delta}{\frac{q_{t+1}}{q_t}}$. This equation can be interpreted as the no arbitrage condition of the household between investing in a riskless bond and physical capital. An increase in investment-specific technology, reflected by an increase in q_t, reduces the amount of consumption good needed to give up in order to invest in one unit of investment good, thus reducing the required rate of return of capital.[11] Arbitrage also implies that a decrease in the gross real interest rate of a riskless bond, $\frac{C_{t+1}}{C_t\beta}$, reduces the rental rate of capital. An increase in the depreciation rate, δ, requires a higher rate of return to invest in capital.

[11] However, an increase in the rate of technology change, $\frac{q_{t+1}}{q_t}$, decreases the capital gain from holding capital, requiring a higher rate of return in order to make the household indifferent between capital and bond, and thus attenuates the decline of the rental rate.

1.4.4 Equilibrium

Given a sequence of exogenous variables, I define an equilibrium for this economy as a sequence of prices:

$$\{W_{nt}, W_{rt}, r_t, p_t(i), p_t^{int}, P_t\}$$

and a sequence of quantities:

$$\{C_t, K_t, I_t, L_{nt}, L_{rt}, Y_t, \bar{\tau}_t, Y_t^m, y_t^f(i), \Pi_t, d_t^f\}$$

such that:

1. Given $\{W_{nt}, W_{rt}, r_t, d_t^f\}$, $\{C_t, K_{t+1}, I_t, \bar{\tau}_t\}$ solves the representative household's problem.

2. Given $\{Y_t, P_t, p_t^{int}\}$, $\{p_t(i), y_t^f(i)\}$ solves the final goods firm i's problem.

3. Given $\{W_{nt}, W_{rt}, r_t\}$, $\{L_{nt}, L_{rt}, K_t, Y_t^m\}$ solves the representative intermediate good firm's problem.

4. Y_t satisfies (1.2), P_t satisfies (1.3) and is normalized to be 1, Π_t satisfies (1.6), d_t^f satisfies (1.7) and Y_t^m satisfies (1.8).

5. Markets for final goods, non-routine task labor, routine task labor and capital need to clear at each period. Final goods market clearing:

$$Y_t = C_t + \frac{I_t}{q_t} \tag{1.15}$$

Labor market clearing:

$$L_{nt} = \int_0^{\bar{\tau}_t} h(\tau) d\tau \tag{1.16}$$

$$L_{rt} = \int_{\bar{\tau}_t}^1 \xi d\tau \tag{1.17}$$

As both the demand and the supply of physical capital at period t are denoted as K_t, it implicitly implies capital market clearing.

1.4.5 Steady State

For a sequence of constant exogenous variables, I define a steady state solution of the model as all endogenous variables being constant, and denoted as $\{W_n, W_r, r, p(i), p^{int}, P\}$ and $\{C, K, I, L_n, L_r, Y, \bar{\tau}, Y^m, y^f(i), \Pi, d^f\}$. Imposing this steady state condition, I obtain the following conditions to characterize the steady state values of the endogenous variables:

$$\frac{W_n}{W_r} = \xi(\bar{\tau})^{\frac{1}{2}} \tag{1.18}$$

$$\beta(r + \frac{1-\delta}{q}) = \frac{1}{q} \tag{1.19}$$

$$I = \delta K \tag{1.20}$$

$$Y = C + \frac{I}{q} \tag{1.21}$$

$$L_n = 2\bar{\tau}^{\frac{1}{2}} \tag{1.22}$$

$$L_r = (1-\bar{\tau})\xi \tag{1.23}$$

$$W_n = \frac{1}{\mu}\Phi_1(1-\Phi_2)Y^{1-\sigma}(\Phi_2 K^\rho + (1-\Phi_2)L_n^\rho)^{\frac{\sigma-\rho}{\rho}} L_n^{\rho-1} \tag{1.24}$$

$$W_r = \frac{1}{\mu}(1-\Phi_1)Y^{1-\sigma}L_r^{\sigma-1} \tag{1.25}$$

$$r = \frac{1}{\mu}\Phi_1\Phi_2 Y^{1-\sigma}(\Phi_2 K^\rho + (1-\Phi_2)L_n^\rho)^{\frac{\sigma-\rho}{\rho}} K^{\rho-1} \tag{1.26}$$

$$Y = [\Phi_1(\Phi_2 K^\rho + (1-\Phi_2)L_n^\rho)^{\frac{\sigma}{\rho}} + (1-\Phi_1)L_r^\sigma]^{\frac{1}{\sigma}} \tag{1.27}$$

$$Y = Y^m = y^f(i) \tag{1.28}$$

$$d^f = \Pi = \frac{\mu-1}{\mu}Y \tag{1.29}$$

$$p(i) = P = 1 \tag{1.30}$$

$$p^{int} = \frac{1}{\mu}P = \frac{1}{\mu} \tag{1.31}$$

Equations (1.18)-(1.31) pins down the steady state values of the endogenous variables.

1.5 Comparative Static Analysis

The qualitative results from the comparative static analysis support the hypothesis that the rise in markups contributes to the post-2000 slowdown of the wage polarization, the wage stagnation of both routine and non-routine occupations, the decline of aggregate labor share and, under a certain range of the elasticities of substitution in the production function, the distinct labor share trend changes across the two occupational groups. These results are summarized by the following propositions.

Proposition 1.5.1 *The following comparative static results hold:*

1. $\frac{\partial K}{\partial \mu} < 0$*. An increase in steady state markups decreases capital stock.*

2. $\frac{\partial W_n}{\partial \mu} < 0$ *and* $\frac{\partial W_r}{\partial \mu} < 0$*. An increase in steady state markups decreases the skill prices of both non-routine task and routine task.*

3. $\frac{\partial \frac{W_n}{W_r}}{\partial \mu} < 0$*. An increase in steady state markups decreases the non-routine wage premium.*

4. $\frac{\partial \bar{\tau}}{\partial \mu} < 0$*. An increase in steady state markups decreases (increases) the employment of workers in non-routine task (routine task).*

Proof. See Appendix A.3. ■

When the market power of the final goods firms increases, they set a higher price over the marginal cost which is the price of the intermediate good. This decreases the real price of the intermediate good (i.e. the price in units of the final goods composites), imposing downward adjustment pressure on both the output and the demand for all factors of production. In particular, it slows down the accumulation of capital and tends to decrease the capital-labor ratio, thus reducing the marginal product of labor and, together with the drop in the real price of the intermediate good, decreasing the skill prices of both tasks. Trough the capital-task complementarity effect, the reduced capital-labor ratio tends disproportionately hurt the non-routine labor, decreasing the non-routine wage premium. A reduced non-routine wage premium induces less worker to be employed in the non-routine task and more in the routine task, thus also reducing the wage-bill ratio of non-routine to routine task, $\frac{W_n L_n}{W_r L_r}$.[12]

The aggregate labor share LS_t, routine labor share RLS_t, non-routine labor share NLS_t, capital share CS_t, profit share PS_t and business cost BC_t are defined by the following equations:

$$LS_t \equiv \frac{W_{nt}L_{nt} + W_{rt}L_{rt}}{Y_t}$$

$$RLS_t \equiv \frac{W_{rt}L_{rt}}{Y_t}$$

$$NLS_t \equiv \frac{W_{nt}L_{nt}}{Y_t}$$

$$CS_t \equiv \frac{r_t K_t}{Y_t}$$

$$PS_t \equiv \frac{\Pi_t}{Y_t}$$

$$BC_t \equiv W_{nt}L_{nt} + W_{rt}L_{rt} + r_t K_t$$

Denote the ratio of aggregate labor income $(W_{nt}L_{nt} + W_{rt}L_{rt})$ to business cost as LC_t, the ratio of routine labor income $(W_{rt}L_{rt})$ to business cost as RLC_t and the ratio of non-routine labor income $(W_{nt}L_{nt})$ to business cost as NLC_t. The definitions of labor share directly imply that labor share can be expressed as the product of the ratio of labor income to business cost and the ratio of business cost to output:

$$LS_t = LC_t(\frac{BC_t}{Y_t}) = LC_t(1 - PS_t)$$

$$RLS_t = RLC_t(\frac{BC_t}{Y_t}) = RLC_t(1 - PS_t)$$

[12]It is easy to see from equations (1.22) and (1.23) that $\frac{\partial \bar{\tau}}{\partial \mu} < 0$ directly implies $\frac{\partial L_n}{\partial \mu} < 0$ and $\frac{\partial L_r}{\partial \mu} > 0$. This, together with $\frac{\partial \frac{W_n}{W_r}}{\partial \mu} < 0$, leads to $\frac{\partial \frac{W_n L_n}{W_r L_r}}{\partial \mu} < 0$.

$$NLS_t = NLC_t(\frac{BC_t}{Y_t}) = NLC_t(1 - PS_t)$$

where the second steps reflect the fact that output is the sum of business cost and profit.

Markups affect labor share through affecting these two components. First, an increase in markups unambiguously increases the profit share. This can be seen directly by equation (1.29) and the definition of profit share. An increase in profit share implies a decrease of business cost relative to output which tends to decrease the labor share in aggregate and across both tasks. Second, an increase in markups changes the labor income relative to business cost through affecting the relative factor quantities-it reduces the capital-labor ratio by slowing down the accumulation of capital and further decreases non-routine to routine labor ratio due to the capital-task complementarity effect. The exact effect on labor income relative to business cost hinges on the range of the elasticities of substitution between capital and labor in different tasks. Under the assumption that non-routine task labor is more complementary with capital than is routine task labor (i.e. $\gamma_n < \gamma_r$), there are three cases to consider regarding the range of γ_n and γ_r: $\gamma_n \geq 1$, $\gamma_r \leq 1$ and $\gamma_n < 1 < \gamma_r$. The effects of these two channels are summarized by the following proposition.

Proposition 1.5.2 *The following comparative static results hold:*

1. $\frac{\partial PS}{\partial \mu} > 0$. *An increase in steady state markups increases the profit share.*

2. $\frac{\partial LC}{\partial \mu} > 0$ *and* $\frac{\partial RLC}{\partial \mu} > 0$ *if* $\gamma_n \geq 1$. *An increase in steady state markups increases both aggregate labor income relative to business cost and routine labor income relative to business cost if* $\gamma_n \geq 1$.

3. $\frac{\partial LC}{\partial \mu} < 0$, $\frac{\partial RLC}{\partial \mu} \leq 0$ *(equal to 0 only if* $\gamma_r = 1$*) and* $\frac{\partial NLC}{\partial \mu} < 0$ *if* $\gamma_r \leq 1$. *An increase in steady state markups (weakly) decreases aggregate labor income relative to business cost, routine labor income relative to business cost and non-routine labor income relative to business cost if* $\gamma_r \leq 1$.

4. $\frac{\partial RLC}{\partial \mu} > 0$ *and* $\frac{\partial NLC}{\partial \mu} < 0$ *if* $\gamma_n < 1 < \gamma_r$. *An increase in steady state markups increases routine labor income relative to business cost and decreases non-routine labor income relative* *to business cost if* $\gamma_n < 1 < \gamma_r$.

Proof. See Appendix A.3. ■

Under the last case where $\gamma_n < 1 < \gamma_r$, $\frac{\partial RLC}{\partial \mu} > 0$ which tends to mitigate the decline in the routine labor share due to the increase in profit share, while $\frac{\partial NLC}{\partial \mu} < 0$ which tends to contribute to the decline in the non-routine labor share jointly with the increase in profit share. The distinct effects of markups on labor share across the two tasks under this case is consistent with the observed post-2000 trend *changes* in labor share across occupations-non-routine labor share turns to decline from the previous rise while there is very limited change in the routine labor share's downward trend.

In Appendix A.2 I show that the investment specific technology tends to increase the non-routine wage premium, skill prices for both tasks, and also has opposite effect to markups for the labor income relative to business cost.

These results support the hypothesis that the investment specific technology drives the long-run trends of non-routine wage premium, skill prices and labor shares, but the rise in markups contributes to the trend *changes* around 2000.

1.6 Quantitative Analysis

Given the focus of this study on the long-term trend changes starting at around 2000, I calibrate the initial steady state of the model to match the level of variables of interest measured at the start of the sample period (1996-2000).[13] Then I compare variables of interest measured at the end of sample period (2011-2015) with those generated at a new steady state that differs from the initial one due to the observed changes in the (smoothed) exogenous variables which are used to capture the changes of the macroeconomic environment. Counterfactual exercises are used to quantify separately the role of each individual exogenous variable.[14]

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[13] Following Karabarbounis and Neiman (2014), I use steady states of the model to represent the simulated trend component of the variables of interest.

[14] The quantitative analysis strategy used here is similar to Chen et al. (2017).

1.6.1 Measurement of the Exogenous Variables

There are four exogenous variables that I consider to capture the changes of the macroeconomic environment that is potentially of quantitative relevance to the variables of interest; these are the investment-specific technology (q_t), markups (μ_t), depreciation rate (δ_t) and discount factor (β_t) (which is used as a shortcut to reflect the changes in the real interest rate of the riskless bond).

The measurement of the investment-specific technology, or the inverse of the relative price of investment goods to consumption goods, is directly obtained from Federal Reserve Economic Data (FRED).[15] I normalize the 5-year moving average of the relative price of the investment goods at the beginning of the sample (1996-2000) to be one .

Depreciation rate is constructed as the ratio of current-cost depreciation to the sum of current-cost depreciation and current-cost net stock of capital using BEA's Fixed Asset Table 4.1 and 4.4.

Real interest rate of the riskless bond is constructed as the Moody's Aaa corporate bond yield minus the expected inflation rate. I use the three-year moving average of the realized inflation rate to proxy the expected inflation rate. Personal Consumption Expenditures Price Index (PCEPI), obtained via FRED, is used to construct the realized inflation rate.

In steady state $\frac{1}{\beta}$ is equal to the gross real interest rate of a riskless bond.[16] Based on this condition, I vary the discount factor as a short cut to account for the variation in the real interest rate.

The five-year moving average of the exogenous variables at the start and end of the sample is shown in Table 1.1.

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[15] Specifically, the measurement of the investment-specific technology is the inverse of the series of PIRIC, which is calculated as investment deflator divided by consumption deflator. (DiCecio (2009))

[16] This condition holds in general with log utility, though for simplicity I don't explicitly introduce the riskless bond in the model.

1.6.2 Calibration

The parameters left to calibrate are efficiency for routine occupation (ξ), weight parameters (ϕ_1, ϕ_2) and elasticities of substitution (γ_n, γ_r) in the production function. The elasticities of substitution would be ideally estimated using micro-level data, but to the best of my knowledge, no reliable micro estimates have been generated in the literature. I instead use the elasticities of substitution estimated using time-series macro-level data by Krusell et al. (2000). The estimates in Krusell et al. (2000) are between skilled, unskilled labor and equipment, which does not exactly match the conceptual framework of this study. However, judging from the skill composition of non-routine and routine occupations and the relative substitutability between labor with different skill level and different types of capital, I treat their estimates as a useful benchmark for this quantitative exercise.[17] Thus, I set $\gamma_n = 0.67$ and $\gamma_r = 1.67$. I then calibrate ϕ_1, ϕ_2 and ξ simultaneously to match the initial level (average between 1996-2000) of routine, non-routine labor share and non-routine wage premium. This gives $\phi_1 = 0.74$, $\phi_2 = 0.54$ and $\xi = 1.36$.

1.6.3 Simulation

Table 1.2 summarizes the results. Row 1 shows values for the agggregate labor share LS, the non-routine labor share NLS, the routine labor share RLS, the non-routine wage premium $\frac{W_n}{W_r}$, the relative labor share (or wage-bill ratio) of non-routine to routine occupations $\frac{NLS}{RLS}$,

[17] It is plausible to assume the skilled and unskilled labor defined in Krusell et al. (2000) using college graduation as the criteria as a combination of high skilled and middle skilled and a combination of middle skilled and low skilled respectively. As indicated by the job polarization literature, routine occupation is mostly associated with middle skilled while non-routine is associated with both high skilled and low skilled. In addition, the job polarisation literature also suggests the substitutability between equipment and labor with different skill level is the strongest for middle skilled, then low skilled and the weakest for high skilled. Thus the elasticity of substitution between routine occupation and equipment should be greater than that between unskilled and equipment. The elasticity of substitution between routine occupation and aggregate capital (which also includes structure), however, should be smaller than that between routine occupation and equipment, as the substitutability effect is weaker for structure than equipment. So I use the estimate of the elasticity of substitution between unskilled and equipment in Krusell et al. (2000) as the benchmark for that between routine occupation and aggregate capital. Similar argument applies for using the estimate of the elasticity of substitution between skilled and equipment for that between non-routine occupation and aggregate capital.

the non-routine skill price W_n, and the routine skill price W_r at the start of the sample (five-year moving average between 1996 and 2000).[18] Row 2 shows the corresponding values generated by the initial steady state of the model. By the calibration procedure, the model matches exactly the data at the start of the sample.

Row 3 lists the observed changes of the variables between the start (1996-2000) and the end (2011-2015) of the sample period. Aggregate labor share in the corporate sector of the United States declined by almost 6.4 percentage points, which was accounted for by a 2.5 percentage point decline of non-routine labor share and a almost 3.9 percentage point decline of routine labor share. Non-routine wage premium increased by close to 5.2 percentage points. The relative labor share of non-routine to routine occupations rose by 85.6 percentage points. Skill prices for non-routine and routine occupations increased by a factor of around 1.17 and 1.11 respectively.

Row 4 has the key results of the analysis. It shows the model-generated changes in the corresponding variables, which are calculated as the difference between the initial and final steady states driven by the observed changes in the exogenous variables, as discussed in Section 1.6.1. The model generates a decline in routine labor share, an increase in non-routine wage premium and relative labor share of non-routine to routine occupations by magnitudes close to the observed changes in the data. It over predicts the skill prices a bit and doesn't generate enough decline in aggregate labor share and non-routine labor share, which suggests other channels not incorporated in this model may be at work and/or the estimated increase in markups could be downward biased.

In the counterfactual analysis, I turn off the effect of each exogenous variable one at a time by reverting it to its initial value while keeping the rest at their end values. Through comparing the results with (row 4) and without (row 5-8) the change of each exogenous variable, it highlights the quantitative role played by each separately.

In row 5, I turn off the channel of investment specific technology. Without the decline in

[18] As mentioned, Skill price is estimated using the Mincerian regression (1.1). Its value is thus an index number and there is no point in matching the level of this index at the start of the sample.

the relative price of investment goods, the aggregate labor share and non-routine labor share would have declined even much more. This contradicts with the claim in Karabarbounis and Neiman (2014) that the decline in the relative price of investment goods reduces the labor share. Their result critically hinges on the condition that the elasticity of substitution between capital and (aggregate) labor is greater than one[19]. While in this quantitative exercise, the elasticity of substitution between capital and non-routine labor is less than one, which drives the effect of investment specific technology on labor share to the opposite direction. This result is consistent with the preponderant evidence that suggests the elasticity of substitution between capital and labor is less than one. The decline of the relative price of investment goods also has a large effect on lowering the routine labor share, increasing the non-routine wage premium, wage-bill ratio and skill prices.

By comparing row 6 with row 4, it shows the increase in markups plays a significant role in the decline of aggregate labor share and non-routine labor share, while a relatively smaller role in the decline of routine labor share. As shown by proposition 1.5.2, under $\gamma_n < 1 < \gamma_r$, the increase in markups reduces non-routine labor income relative to business cost and raises profit share, both of which tend to reduce non-routine labor share. While routine labor income relative to business cost is raised by rising markups, which tends to offset the effect of rising profit share on driving the decline of routine labor share. The increase in markups also significantly suppresses the growth of skill prices across both occupations, reduces the non-routine labor share relative to routine labor share, slows down the increase of non-routine wage premium. All these results are consistent with the qualitative analysis.

In row 7, I remove the decline in the real interest rate. This leads to significant changes on all variables of interest. Qualitatively, these effects are the same with those of the investment specific technology, as both the decline in the real interest rate and the decline in the relative price of investment goods affect the variables of interest through lowering the rental cost of

[19]Karabarbounis and Neiman (2014) estimates the elasticity of substitution between capital and labor using cross-country variation in trends in the rental rates and labor shares. Their baseline estimated value is 1.25.

capital.

The depreciation rate doesn't change by much over the sample period. Removing this change in row 8 has no large effect on the variables of interest.

As discussed in the qualitative analysis, the increase in markups affects labor income relative to business cost, non-routine wage premium and skill prices through slowing down the accumulation of capital. I evaluate the model performance of investment, capital stock and investment rate in Table 1.3. The variables I, K, Y, I/q and $(I/q)/Y$ denote investment in efficiency unit, capital stock in efficiency unit, output in units of consumption goods, investment in units of consumption goods and investment rate. The model produces a 20 percent investment rate which is very close to the 19 percent observed investment rate at the start of sample. The model-generated changes in investment and investment rate are a bit higher than the observed changes in the data. Comparing row 6 with row 4, it nevertheless shows the quantitatively significant role played by the rising markups in slowing down the accumulation of capital, reducing the investment and investment rate.

Given the large range of magnitude of increase in markups estimated in the literature, in the following exercise, I ask what would be the end value of markups that could fully account for the observed decline of the aggregate labor share and under this value how well this model could capture the changes of other variables of interest.

The simulation shows it requires the end value of markups to be 1.23 and this implies a 19 percentage points increase in markups over the sample period. The magnitude of increase would be close to the upper end of range estimated in the literature.[20] Table 1.4 summarises the results. As shown by row 4, by construction, the model-generated change in aggregate labor share matches exactly the observed change. The magnitudes of changes in non-routine labor share, routine labor share, non-routine wage premium, and relative labor share are all very close to those observed in the data. Under this higher end value of markups the model

[20] In Hall (2018), the estimated markups increase by 14.4 percentage points on average in 15 years. In De Loecker and Eeckhout (2017), the increase is approximately 20 percentage points (1.4 to 1.6) from 1998 to 2013.

over suppresses the growth in the skill prices. Given the potential measurement issues of skill prices, however, the model-generated growth of skill prices may still fall in a reasonable range. As already mentioned, the estimates of skill prices in Eden and Gaggl (2018) exhibits almost no growth after 2000; the model-generate changes in the skill prices are close to their estimates.

The model performance of investment, capital stock and investment rate is summarized in Table 1.5. With the higher end value of markups, the model-generated changes in investment and investment rate are a bit lower than the observed changes but still close. The accumulation of capital stock is under predicted.

It is a plausible scenario that the magnitude of increase in markups lies between those implied by the two end values shown in the analysis, so the model could account for a bulk of the observed trend changes of the variables of interest. Factors other than markups may also contribute to the trend changes. Nevertheless, even with the lower end value of markups, the counterfactual analysis still indicates that the increase in markups has a quantitatively large effect on most of the variables of interest.

1.7 Empirical Evidence

In this section, I exploit the cross-industry variation in market power and variables of interest to present correlational evidence for several testable hypothesis derived from the model. In particular, assuming labor mobility is imperfect across industries, the model predicts industries with larger increase in (average) markups will experience smaller increase in non-routine wage premium, smaller increase in skill prices across both routine and non-routine occupations, (tend to experience) larger decrease in labor share in aggregate and across both occupations, smaller increase in the wage-bill ratio of non-routine to routine occupations.

I use the change in market concentration-share of sales by the 4, 8, 20 and 50 largest firms-as a proxy to the change in market power at the industry level. This proxy in general may not be valid, as both a decrease and an increase in competition could lead to an increase in market concentration, as argued in Syverson (2019). However, for the post-2000 period, which is the focus of this study, Covarrubias et al. (2019) shows the increase in concentration is associated with a rise in markups (decline in competition).

I obtain payrolls, sales and concentration by industry at 6-digit NAICS level for year 2002, 2007 and 2012 from US Economic Census' Concentration accounts. Following Barkai (2016), I construct aggregate labor share by industry as the payroll labor share of sales and restrict the samples from Census data to the industries that are consistently defined overtime. I then merge CPS data and Census data based on crosswalk between NAICS and Census industry code provided by Soltas (2019).[21] Table 1.6 reports descriptive statistics of the concentration ratios and variables of interest of the matched sample.

The empirical specification is a reduced form regression in log differences assessing the cross-sectional correlation across industries between change in concentration and change in variables of interest:

$$\Delta_5 log(Z_{j,t}) = \beta \Delta_5 log(CR^n_{j,t}) + \gamma_t + \epsilon_{j,t} \tag{1.32}$$

where j and t are the indexes for industry and year respectively, Δ_5 denotes a 5-year change, $Z_{j,t}$ is the variable of interest, $CR^n_{j,t}$ is the share of sales by the n largest firms $(n = 4, 8, 20, 50)$ and γ_t is the year fixed effect. The two separate time windows are 2002-2007 and 2007-2012. Standard errors are clustered at the industry level.

Table 1.7 summarises the results for n=20. The regression coefficients are negative and statistically significant at conventional levels for the regressions of aggregate labor share (2), labor share across both occupations (3,4) and skill prices across both occupations (5,6) on concentration ratios. It indicates rising concentration is associated with the decline in aggregate labor share and labor share across both occupations, the slowdown in the growth of skill prices across both occupations, providing suggestive evidence for the corresponding testable hypotheses. However, the coefficients for the regressions of non-routine wage premium (1) and wage-bill ratio (7) are statistically insignificant at conventional levels. The regressions

[21] Within the consistently defined 6-digit NAICS industries, each is mapped into one Census industry. I aggregate the concentration ratios and labor shares to Census industries by taking a sales-weighted average.

using n=4,8,50 show similar results.[22]

The results that the industries experiencing larger increase in concentration are associated with a larger decline in skill prices supports the claim that the post-2000 increase in concentration is an inefficient outcome due to decline in competition and rise in market power, which is consistent with the conclusions in Covarrubias et al. (2019), but contradicts with the argument in Autor et al. (2017). Autor et al. (2017) argues that if globalization or technological changes drive the expansion of the most productive firms in each industry, product market concentration will rise and aggregate labor share will decline as industries become increasingly dominated by superstar firms, which have a low labor share of value-added. Since more productive firms tend to have a higher marginal product of labor, the argument should imply rising concentration is associated with a higher growth of skill price, which is at odds with the results here.

1.8 Conclusion

In this paper, I develop a general equilibrium model to provide a unified explanation based on the rising market power for a set of post-2000 labor market trends, including the stagnation of wage growth, the slowdown of wage polarization, the decline of aggregate labor share and the distinct labor share trends across routine and non-routine occupations. The calibrated model can quantitatively account for the trends with the magnitude of increase in markups close to the higher end of range in the literature. Using cross-industry variation, I find suggestive evidence supporting most of the testable hypotheses.

As the quantitative effect of market power hinges on the elasticities of substitution between capital and labor in routine and non-routine tasks, one potential path for future research is to get more precise estimates of these parameters. The cross-industry correlation examined in the paper does not suggest tight associations between market power and the non-routine wage premium and the wage-bill ratio of non-routine to routine occupations;

[22] See Appendix A.4 for the results for n=4,8,50.

designing better empirical strategy to identify the causal effects of market power on the variables of interest is left for future research.

Tables

Table 1.1: **5-year Moving Average of the Exogenous Variables**

	1996-2000	2011-2015
$\frac{1}{q}$	1.0000	0.6462
μ	1.0377	1.1234
$\frac{1}{\beta}$	1.0548	1.0263
δ	0.0824	0.0820

Notes: The table summarizes the values of the 5-year moving average of the exogenous variables of the model at the beginning (1996-2000) and at the end (2011-2015) of the sample. The variables q, μ, β and δ denote investment-specific technology, markups, discount factor and depreciation rate. Investment-specific technology is taken from FRED and is normalized to be one at the beginning of the sample. Markups are imputed from the profit share under the assumption of constant return to scale of production. Discount factor is used as a short cut to account for the variation in the real interest rate of the riskless bond which is constructed as the Moody's Aaa corporate bond yield minus the expected inflation rate. The three-year moving average of the realized inflation rate is used to proxy the expected inflation rate. Personal consumption expenditures index (PCEPI), obtained via FRED, is used to construct the realized inflation rate. Depreciation rate is constructed as the ratio of current-cost depreciation to the sum of current-cost depreciation and current-cost net stock of capital using BEA's Fixed Asset Table 4.1 and 4.4.

Table 1.2: **Model Results on Labor Market Trends with μ_1=1.123**

μ_0=1.038, μ_1=1.123							
Start of sample (1996-2000)	LS	NLS	RLS	Wn/Wr	NLS/RLS	Wn	Wr
1.Data	0.6294	0.4774	0.1520	1.0637	3.1413	index	index
2.Model	0.6294	0.4774	0.1520	1.0637	3.1413	index	index
End of sample (2011-2015; Δ)	LS	NLS	RLS	Wn/Wr	NLS/RLS	Wn(fac.)	Wr(fac.)
3.Data	-0.0639	-0.0250	-0.0388	0.0517	0.8563	1.1659	1.1116
4.Model	-0.0037	0.0288	-0.0325	0.0579	1.0946	1.2388	1.1749
Counterfactuals (Δ)	LS	NLS	RLS	Wn/Wr	NLS/RLS	Wn(fac.)	Wr(fac.)
5.No q	-0.0361	-0.0182	-0.0179	0.0175	0.2829	1.0055	0.9892
6.No μ	0.0541	0.0792	-0.0251	0.0641	1.2443	1.3874	1.3086
7.No β	-0.0208	0.0044	-0.0252	0.0377	0.6575	1.1133	1.0752
8.No δ	-0.0039	0.0284	-0.0324	0.0576	1.0879	1.2369	1.1734

Notes: The table summarizes the model results on labor market trends with the end value of markups, μ_1, as 1.123. Row 1 shows the values of the variables of interest at the start of the sample (1996-2000). Row 2 shows the corresponding values generated by the initial steady state of the model which, by the calibration procedure, matches the data exactly. Row 3 lists the observed changes of the variables between the start (1996-2000) and the end (2011-2015) of the sample. Row 4 shows the model-generated changes. Row 5 to 8 show the counterfactual changes with one of the exogenous variables reverted to its initial value. Row 3 to 8 show the changes of W_n and W_r in factors, and the changes of the rest variables of interest in levels. μ_0 and μ_1 denote the value of markups at the start and at the end of the sample, respectively.

Table 1.3: **Model Results on Investment with μ_1=1.123**

μ_0=1.038, μ_1=1.123			
Start of sample (1996-2000)	I	K	(I/q)/Y
1.Data	index	index	0.1903
2.Model	index	index	0.2008
End of sample (2011-2015; Δ)	I(fac.)	K(fac.)	(I/q)/Y
3.Data	1.8112	2.1555	-0.0046
4.Model	1.9013	1.9104	-0.0005
Counterfactuals (Δ)	I(fac.)	K(fac.)	(I/q)/Y
5.No q	1.1894	1.1951	0.0240
6.No μ	2.0626	2.0724	0.0113
7.No β	1.4867	1.4938	-0.0320
8.No δ	1.9033	1.9033	-0.0001

Notes: The table summarizes the model results on investment, capital stock and investment rate with the end value of markups, μ_1, as 1.123. Row 1 shows the values of the variables of interest at the start of the sample (1996-2000). Row 2 shows the corresponding values generated by the initial steady state of the model. Row 3 lists the observed changes of the variables between the start (1996-2000) and the end (2011-2015) of the sample. Row 4 shows the model-generated changes. Row 5 to 8 show the counterfactual changes with one of the exogenous variables reverted to its initial value. Investment and capital stock are restricted to non-residential. Investment in efficiency unit, I, and capital stock in efficiency unit, K, are constructed as the ratio of the nominal values to the investment deflator (INVDEF, from FRED). Output in units of consumption goods, Y, is the ratio of nominal output to consumption deflator (CONSDEF, from FRED). Row 3 to 8 show the changes of I and K in factors, and the changes of $\frac{(I/q)}{Y}$ in levels. μ_0 and μ_1 denote the value of markups at the start and at the end of the sample, respectively.

Table 1.4: **Model Results on Labor Market Trends with μ_1=1.23**

μ_0=1.038, μ_1=1.23							
Start of sample (1996-2000)	LS	NLS	RLS	Wn/Wr	NLS/RLS	Wn	Wr
1.Data	0.6294	0.4774	0.1520	1.0637	3.1413	index	index
2.Model	0.6294	0.4774	0.1520	1.0637	3.1413	index	index
End of sample (2011-2015; Δ)	LS	NLS	RLS	Wn/Wr	NLS/RLS	Wn(fac.)	Wr(fac.)
3.Data	-0.0639	-0.0250	-0.0388	0.0517	0.8563	1.1659	1.1116
4.Model	-0.0639	-0.0236	-0.0403	0.0504	0.9240	1.0867	1.0376
Counterfactuals (Δ)	LS	NLS	RLS	Wn/Wr	NLS/RLS	Wn(fac.)	Wr(fac.)
5.No q	-0.0938	-0.0675	-0.0262	0.0076	0.1186	0.8750	0.8688
6.No μ	0.0541	0.0792	-0.0251	0.0641	1.2443	1.3874	1.3086
7.No β	-0.0798	-0.0465	-0.0333	0.0290	0.4895	0.9727	0.9468
8.No δ	-0.0642	-0.0239	-0.0402	0.0501	0.9173	1.0850	1.0362

Notes: The table summarizes the model results on labor market trends with the end value of markups, μ_1, as 1.23. Row 1 shows the values of the variables of interest at the start of the sample (1996-2000). Row 2 shows the corresponding values generated by the initial steady state of the model which, by the calibration procedure, matches the data exactly. Row 3 lists the observed changes of the variables between the start (1996-2000) and the end (2011-2015) of the sample. Row 4 shows the model-generated changes. Row 5 to 8 show the counterfactual changes with one of the exogenous variables reverted to its initial value. Row 3 to 8 show the changes of W_n and W_r in factors, and the changes of the rest variables of interest in levels. μ_0 and μ_1 denote the value of markups at the start and at the end of the sample, respectively.

Table 1.5: **Model Results on Investment with μ_1=1.23**

μ_0=1.038, μ_1=1.23			
Start of sample (1996-2000)	I	K	(I/q)/Y
1.Data	index	index	0.1903
2.Model	index	index	0.2008
End of sample (2011-2015; Δ)	I(fac.)	K(fac.)	(I/q)/Y
3.Data	1.8112	2.1555	-0.0046
4.Model	1.7299	1.7382	-0.0133
Counterfactuals (Δ)	I(fac.)	K(fac.)	(I/q)/Y
5.No q	1.0737	1.0788	0.0092
6.No μ	2.0626	2.0724	0.0113
7.No β	1.3473	1.3537	-0.0429
8.No δ	1.7316	1.7316	-0.0129

Notes: The table summarizes the model results on investment, capital stock and investment rate with the end value of markups, μ_1, as 1.23. Row 1 shows the values of the variables of interest at the start of the sample (1996-2000). Row 2 shows the corresponding values generated by the initial steady state of the model. Row 3 lists the observed changes of the variables between the start (1996-2000) and the end (2011-2015) of the sample. Row 4 shows the model-generated changes. Row 5 to 8 show the counterfactual changes with one of the exogenous variables reverted to its initial value. Investment and capital stock are restricted to non-residential. Investment in efficiency unit, I, and capital stock in efficiency unit, K, are constructed as the ratio of the nominal values to the investment deflator (INVDEF, from FRED). Output in units of consumption goods, Y, is the ratio of nominal output to consumption deflator (CONSDEF, from FRED). Row 3 to 8 show the changes of I and K in factors, and the changes of $\frac{(I/q)}{Y}$ in levels. μ_0 and μ_1 denote the value of markups at the start and at the end of the sample, respectively.

Table 1.6: **Descriptive Statistics**

	N	Mean	Median	S.D.	Min	Max
Value in 2002						
Sales Share of 4 Largest Firms	174	33.15	30.20	19.57	0.80	92.98
Sales Share of 8 Largest Firms	174	42.25	40.81	22.48	1.40	98.35
Sales Share of 20 Largest Firms	174	52.85	54.42	24.79	2.20	99.82
Sales Share of 50 Largest Firms	174	62.16	64.42	26.10	3.40	100.00
Non-routine Wage Premium	174	114.76	112.01	24.86	38.84	204.99
Aggregate Labor Share	113	24.26	18.02	20.21	1.34	153.78
Non-routine Labor Share	113	19.03	13.74	17.78	1.15	135.62
Routine Labor Share	113	5.24	4.08	4.83	0.19	37.39
Wage-bill ratio	174	481.22	187.31	1419.94	13.59	18086.21
Value in 2012						
Sales Share of 4 Largest Firms	173	34.92	32.30	19.62	0.80	91.26
Sales Share of 8 Largest Firms	173	44.24	42.56	22.47	1.10	100.00
Sales Share of 20 Largest Firms	174	55.33	58.12	24.83	1.80	100.00
Sales Share of 50 Largest Firms	174	64.60	69.90	25.87	3.10	100.00
Non-routine Wage Premium	174	115.00	113.80	27.59	25.29	235.94
Aggregate Labor Share	113	22.86	18.44	16.07	0.51	98.82
Non-routine Labor Share	113	18.33	14.87	14.28	0.40	60.28
Routine Labor Share	113	4.53	3.55	4.33	0.06	38.53
Wage-bill ratio	174	933.03	195.35	6212.60	4.68	81629.09
Change in Value (2002-2012)						
Sales Share of 4 Largest Firms	173	1.92	1.42	6.84	-40.38	25.01
Sales Share of 8 Largest Firms	173	2.10	2.00	6.72	-38.45	27.62
Sales Share of 20 Largest Firms	174	2.49	2.37	5.88	-36.01	23.08
Sales Share of 50 Largest Firms	174	2.44	2.15	5.33	-33.34	15.40
Non-routine Wage Premium	174	0.23	1.53	34.19	-120.14	112.70
Aggregate Labor Share	113	-1.40	-0.71	10.32	-107.43	9.99
Non-routine Labor Share	113	-0.70	-0.24	9.32	-93.93	13.90
Routine Labor Share	113	-0.71	-0.28	2.74	-18.73	4.95
Wage-bill ratio	174	451.81	15.59	4870.41	-2137.58	63542.88
Log-Change in Value (2002-2012)						
Sales Share of 4 Largest Firms	173	0.08	0.07	0.25	-1.69	0.72
Sales Share of 8 Largest Firms	173	0.07	0.06	0.21	-1.37	0.63
Sales Share of 20 Largest Firms	174	0.06	0.04	0.17	-1.09	0.58
Sales Share of 50 Largest Firms	174	0.05	0.04	0.14	-0.88	0.53
Non-routine Wage Premium	174	-0.01	0.01	0.31	-1.67	1.36
Aggregate Labor Share	113	-0.06	-0.03	0.20	-1.20	0.45
Non-routine Labor Share	113	-0.03	-0.01	0.30	-1.18	1.08
Routine Labor Share	113	-0.17	-0.10	0.52	-2.40	1.37
Wage-bill ratio	174	0.11	0.07	0.66	-1.81	2.89
Non-routine Skill Price	174	0.02	0.30	3.12	-31.28	7.13
Routine Skill Price	174	0.02	0.30	3.11	-30.71	7.18

Table 1.7: **Wage Premium, Labor Share, Skill Prices and Wage-bill Ratio on Industry Concentration**

	(1) $\Delta_5 \log(\frac{W_n}{W_r}(\%))$	(2) $\Delta_5 \log(LS)$	(3) $\Delta_5 \log(NLS)$	(4) $\Delta_5 \log(RLS)$	(5) $\Delta_5 \log(W_r)$	(6) $\Delta_5 \log(W_n)$	(7) $\Delta_5 \log(\frac{W_n L_n}{W_r L_r})$
$\Delta_5 log(CR^{20})$	0.050	-0.262***	-0.252***	-0.389***	-1.632**	-1.582**	0.167
	(0.091)	(0.086)	(0.093)	(0.146)	(0.752)	(0.743)	(0.146)
Year FE	Y	Y	Y	Y	Y	Y	Y
R^2	.017	.077	.028	.017	.0071	.0078	.0028
Observations	348	226	224	224	348	348	346

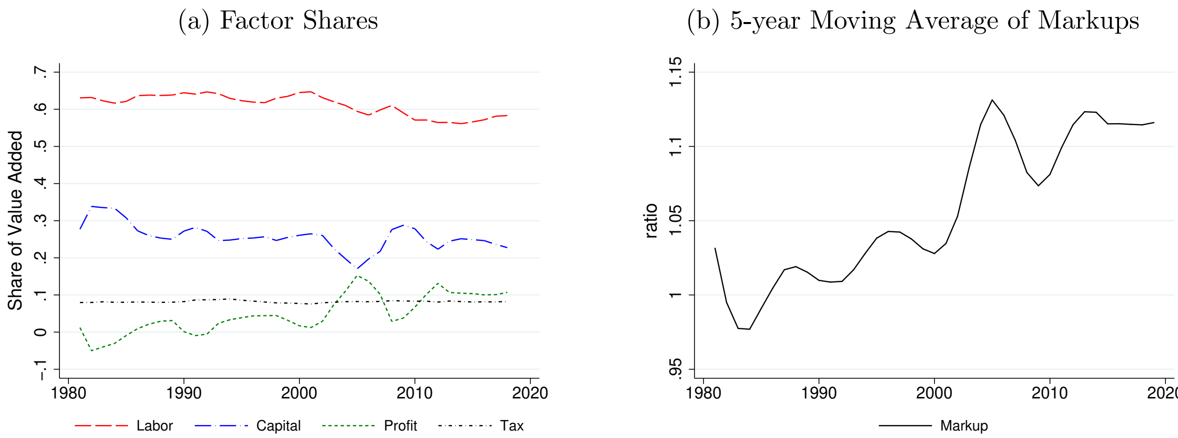
Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table reports results of industry-level regressions of contemporaneous 5-year log-changes in non-routine wage premium, aggregate labor share, non-routine labor share, routine labor share, skill price of routine occupation, skill price of non-routine occupation and wage-bill ratio of non-routine to routine occupation on 5-year log-changes in industry concentration. The unit of observation is a Census industry. CR^{20} denotes the share of sales by the 20 largest firms within a industry. Standard errors are clustered at industry level.

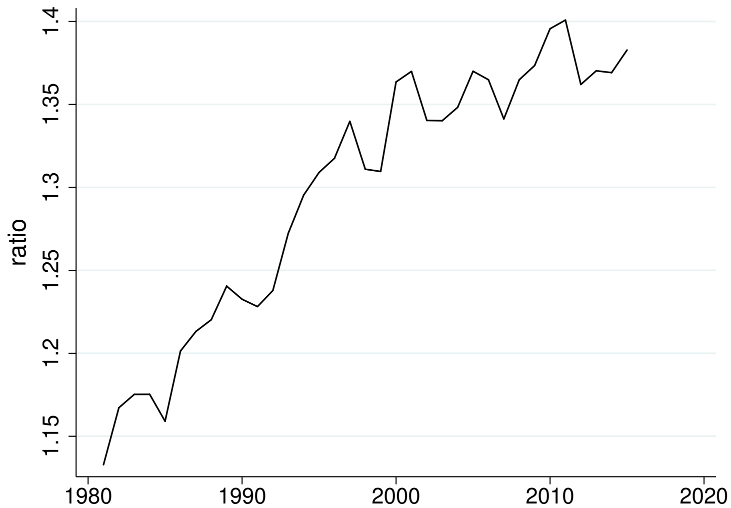
Figures

Figure 1.1: **Factor Shares and Markups**



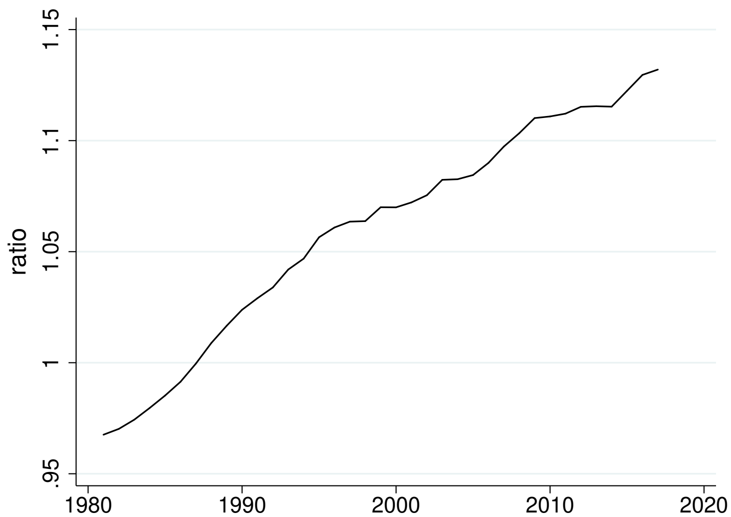
Notes: The figure shows factor shares and 5-year moving average of markups for the US corporate sector. Factor shares include labor share, capital share, profit share and tax share. Markups are imputed from the profit share under the assumption of constant return to scale of production.

Figure 1.2: **Non-routine Raw Average Wage Premium**



Notes: The figure shows the non-routine raw average wage premium, i.e. the ratio of the average real wage in units of dollars per hour worked of non-routine occupations to routine occupations.

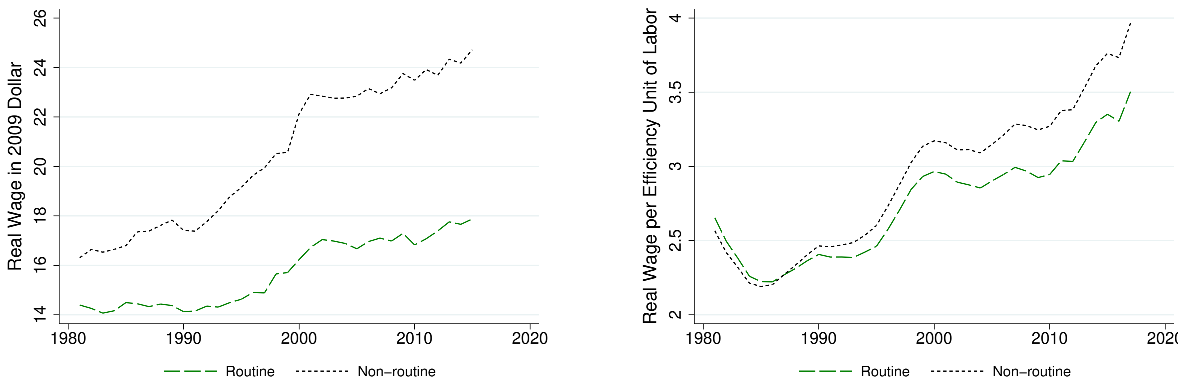
Figure 1.3: **5-year Moving Average of Non-routine Wage Premium**



Notes: The figure shows the 5-year moving average of non-routine wage premium, i.e. the ratio of the average skill price (real wage per efficiency unit of labor) of non-routine occupations to routine occupations. Skill prices are constructed using the Mincerian regression (1.1) to control for the education and demographic factors. The regression is weighted by sampling weights.

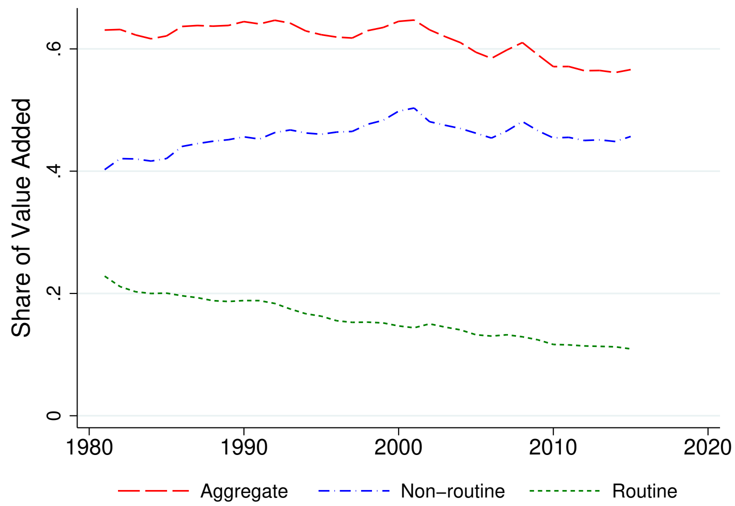
Figure 1.4: **Wages by Occupations**

(a) Raw Average Wage (b) 5-year Moving Average of Skill Prices



Notes: The figure shows the wages by routine and non-routine occupations. Panel (a) shows the raw average wages, i.e. the real wages per hour worked by occupations. Panel (b) shows the 5-year moving average of skill prices, i.e. real wages per efficiency unit of labor. Skill prices are constructed using the Mincerian regression (1.1) to control for the education and demographic factors. The regression is weighted by sampling weights.

Figure 1.5: **Labor Share by Occupations**



Notes: The figure shows aggregate labor share and labor share by routine and non-routine occupations for the US corporate sector. Aggregate labor share is decomposed into routine labor share and non-routine labor share based on the earnings ratio of the two occupation groups at each year using data on wage and salary income from the ASEC of CPS.

Chapter 2

THE EFFECTS OF GLOBALIZATION ON SKILLED LABOR, UNSKILLED LABOR AND SKILL PREMIUM[1]

2.1 Introduction

The globalization in the last four decades has been characterized by dramatic tariff reductions and capital account liberalizations manifested by enormous increases in cross-border holdings of gross financial assets and liabilities (Turnovsky and Rojas-Vallejos (2018); Lane and Milesi-Ferretti (2007, 2018)). Over a similar period, skill premium, the relative wage of skilled labor to unskilled labor, has increased across a large group of developed and developing countries (Parro (2013)). These concurrent developments naturally raises the question of the nature of the link (if any) between globalization and the skill premium. In this paper, we develop a dynamic general equilibrium model to jointly assess the effects of consumption tariff reduction, materials tariff reduction and capital account liberalization, on the skilled labor, unskilled labor and skill premium, both in the long run and along the transitional path.

The model we employ is a dynamic general equilibrium model with two types of labor. Unskilled labor earns income only from providing labor, while skilled workers, in addition to providing labor, also engage in investment and have access to an international financial market where they can borrow or lend, but are subject to financial frictions that are reflected in costs that increase with the domestic economy's position in the financial market. Both types of households consume a domestically produced tradeable good and an imported consumption good which is subject to a consumption tariff. Firms hires both types of labor, rent domestic capital and purchase imported raw materials that are subject to a materials

[1] This chapter is a joint work with Stephen Turnovsky from the University of Washington.

tariff. Following Krusell et al. (2000), a key feature of the production function is that capital is more complementary with skilled labor than it is with unskilled labor.

The complexity of the model necessitates its numerical analysis. Our benchmark calibration is for a generic debtor economy, and to facilitate our understanding of the diverse mechanisms involved as the economy adjusts over time we introduce reduction in consumption tariff, reduction in materials tariff and financial liberalization, manifested as a reduction in the costs associated with trading in international financial markets, sequentially in the simulation.

Upon impact, both forms of the tariffs reduction drive up the relative price of imported goods, raising the burden of servicing the debt (denominated in imported goods) and inducing the skilled labor to increase working hours, which reduces the skill premium. As the economy adjust over time, however, the effects from the two forms of tariffs reduction contrast sharply with each other. While raising the demand for imported consumption, reduction in consumption tariff lowers the demand for domestic consumption good, imposing downward adjustment pressure on the output of domestic firms. This in turn lowers the demand for capital. As capital drops gradually, due to its complementarity with the skilled labor, it further reduces the skill premium. Reduction in materials tariff, on the other hand, lowers the cost of production, boosts output and increases the demand for all other factors of production. In particular, capital increases over time and it gradually offsets the initial decline in the skill premium and eventually leads to an increase. Quantitatively, our simulation suggests the effect of consumption tariff reduction on the skill premium is small relative to the comparable reduction in materials tariff.

Financial liberalization, in contrast, works through a very different mechanism.[2] On impact, by lowering the borrowing cost it induces the the skilled labor to reduce working hours, which increases the skill premium. Along the transitional path, there are two countervailing forces that drive the evolution of the skill premium. On one hand, the reduced borrowing cost

[2]We use the terms "financial liberalization" and "capital account liberalization" interchangeably in this chapter and Chapter 3.

gives the skilled labor an incentive to accumulate capital through issuing new debt, which tends to raise the skill premium. On the other hand, the growing burden of servicing the debt induces the skilled labor to increase working hours, which tends to have the opposite effect on the skill premium. Initially, the effect from the rapid accumulation of capital dominates that of the increasing supply of skilled labor, and the skill premium further increases. As the accumulation of capital slows down and the latter effect gains strength, the skill premium reaches its peak and starts to decline in around 10 periods and eventually drops below the initial level.

2.2 Related Literature

There is an extensive empirical literature studying the impact of international trade on the skill premium; See Goldberg and Pavcnik (2007) for a survey of earlier works. Overall, the empirical evidence is inconclusive, with results usually hinging on the economy, period, data set and methodology employed. On the theoretical front, the failure of traditional Heckscher-Ohlin trade model to account for the rising skill premium in developing countries has prompted researchers to explore other mechanisms through which international trade may affect the skill premium; see, for example, Acemoglu (2003), Thoenig and Verdier (2003), Yeaple (2005), Matsuyama (2007) and Monte (2011). Two recent theoretical papers along these lines, and closely related to our approach, are Parro (2013) and Burstein et al. (2013), both of which examine the role of imports of capital goods under the assumption of capital-skill complementarity using a structural quantitative trade model. Different from, and complementary to, their papers, we embed the capital-skill complementarity in a dynamic general equilibrium model to study both the long-run effects and transitional dynamics of tariff reductions, and in light of recent empirical papers which highlight the roles of different forms of tariff (e.g.Amiti and Cameron (2012) and Estevadeordal and Taylor (2013)), we distinguish between consumption tariff and materials (intermediate input) tariff, and contrast their respective consequences. The on-impact effect on the skill premium shown by our simulation is consistent with the empirical findings of Amiti and Cameron (2012) in which the authors find a contemporaneous causal effect of reduction in input tariff to reduce the skill premium within firms that import their intermediate inputs using data for Indonesia.

While there is a vast literature studying the implications of trade liberalization on the skill premium, the literature for that of capital account liberalization is very sparse. To the best of our knowledge, the only paper that directly studies this is Larrain (2015). Using aggregate data and exploiting variation in the timing of capital account openings across 20 mainly European countries, Larrain (2015) finds that opening the capital account increases the skill premium by 5%, and the increase seems to be persistent for the 10 years after the capital account liberalization, which is broadly consistent with our numerical results.[3] Our paper also relates to the broader literature which studies the effects of capital account liberalization on inequality in general. Two recent paper of this are Furceri and Loungani (2018) and Furceri et al. (2019).[4] Based on panel data estimates for 149 countries from 1970 to 2010, Furceri and Loungani (2018) find episodes of capital account liberalization increase the Gini measure of inequality. The country-level results in Furceri et al. (2019), which are based on 228 capital account liberalization episodes spanning 149 advanced and developing economies from 1970 to the present, suggests capital account liberalizations contribute to significant increases in Gini coefficient and decreases in labor share of income. The increase in inequality estimated in both papers seems to be persistent for the five years after the liberalization. While this line of research is predominantly empirical, our paper highlights the theoretical mechanisms linking capital account liberalization and skill premium, and quantifies both the short-run and long-run effects using a dynamic general equilibrium model.

2.3 Macroeconomic Framework

The economy comprises two types of labor, a fraction, θ, of which are unskilled and the remainder, $1 - \theta$, are skilled. Both classes of workers are endowed with a unit of time that they can allocate between working and leisure. Unskilled labor earns income only

[3] See Figure 1 in Larrain (2015).

[4] Earlier studies include Das and Mohapatra (2003) and Jayadev (2007).

from providing labor, while skilled workers, in addition to providing labor, also engage in investment and have access to an international financial market where they can borrow or lend. Both types of households consume a domestically produced tradeable good and an imported consumption good. The relative international price of the latter is p, in addition to which it is subject to a tariff, τ_c.

2.3.1 Firms

Firms hire both types of labor, (denoted by N_U and N_S respectively), rent domestic capital (K), and purchase imported raw materials (m), to produce domestic output in accordance with the linearly homogeneous neoclassical production function $F\left(K, \theta N_U, (1-\theta)N_S, m\right)$, The relative price of imported raw materials is also p and it is subject to a tariff, τ_m. Firms are assumed to maximize profits, and in the absence of any frictions or costs of adjustment the equilibrium rates of return to capital, r_K, wage rates earned by unskilled and skilled workers, w_U and w_S are

$$r_K = F_K\left(K, \theta N_U, (1-\theta)N_S, m\right) \tag{2.1a}$$

$$w_U = F_{(\theta N_U)}\left(K, \theta N_U, (1-\theta)N_S, m\right) \tag{2.1b}$$

$$w_S = F_{(1-\theta)N_s}\left(K, \theta N_U, (1-\theta)N_S, m\right) \tag{2.1c}$$

while equilibrium in the market for imported raw materials is described by

$$p\left(1+\tau_m\right) = F_m\left(K, \theta N_U, (1-\theta)N_S, m\right) \tag{2.1d}$$

2.3.2 Household

The government uses the revenues it generates from the two tariffs to provide a pure public consumption good, G, that impacts the utility of all workers, skilled and unskilled, equally. For simplicity this is introduced additively in their utility function and accordingly has no influence on their decisions.

Unskilled Labor

We assume that the objective of the representative unskilled worker is to choose his consumption of the domestic and imported good, $C_{U,D}$, $C_{U,M}$, respectively, and his fraction of time allocated to leisure, l_U, to maximize the following constant elasticity utility function

$$\text{Max} \int_0^\infty \left[\frac{1}{\gamma} \left(C_{U,D}^{\phi} C_{U,M}^{1-\phi} l_U^{\eta} \right)^{\gamma} + \chi(G) \right] e^{-\beta t} dt \tag{2.2a}$$

where $1/(1-\gamma)$ is the worker's intertemporal elasticity of substitution, ϕ measures the relative importance of the domestic versus the imported consumption good, η reflects the relative importance of leisure, and β is the rate of time preference. The remaining restrictions in (2.2a) are imposed to ensure concavity of the utility function in its three arguments. These decisions are made subject to the budget constraint

$$C_{U,D} + p\,(1+\tau_c)\,C_{U,M} = (1-l_U)\,w_U \tag{2.2b}$$

which is purely static due to the assumption that unskilled workers cannot borrow or save.

The optimality conditions are:

$$\phi C_{U,D}^{\phi\gamma-1} C_{U,M}^{(1-\phi)\gamma} l_U^{\eta\gamma} = \lambda_U \tag{2.3a}$$

$$(1-\phi) C_{U,D}^{\phi\gamma} C_{U,M}^{(1-\phi)\gamma-1} l_U^{\eta\gamma} = p\,(1+\tau_c)\,\lambda_U \tag{2.3b}$$

$$\eta C_{U,D}^{\phi\gamma} C_{U,M}^{(1-\phi)\gamma} l_U^{\eta\gamma-1} = \lambda_U w_U \tag{2.3c}$$

where λ_U is the unskilled worker's marginal utility of wealth. Denoting the unskilled agent's total consumption in terms of the domestic good and inclusive of the consumption tariff by

$C_U \equiv C_{U,D} + p\,(1+\tau_c)\,C_{U,M}$, we may express the agent's consumption expenditures as:

$$C_{U,D} = \phi C_U = \phi \frac{w_U}{1+\eta} \tag{2.4a}$$

$$p\,(1+\tau_c)\,C_{U,M} = (1-\phi)C_U = (1-\phi)\frac{w_U}{1+\eta} \tag{2.4b}$$

while his allocation of time to leisure is a constant, that increases with the utility elasticity of leisure

$$l_U = \frac{\eta}{1+\eta} \tag{2.4c}$$

Note that clearance of labor market implies $N_U + l_U = 1$, i.e. $N_U = (1+\eta)^{-1}$.

Skilled Labor

The representative skilled worker faces an analogous optimization problem:

$$\text{Max} \int_0^\infty \left[\frac{1}{\gamma} \left(C_{S,D}^{\phi} C_{S,M}^{1-\phi} l_S^{\eta} \right)^{\gamma} + \chi(G) \right] e^{-\beta t} dt \tag{2.5a}$$

where the subscript "S" denotes "skilled" and for simplicity we assume that skilled and unskilled workers enjoy the same tastes. In contrast to unskilled workers, their decisions are subject to the debt accumulation equation, expressed in terms of units of domestic output:

$$p\dot{z} = i\left(\frac{pZ}{K}\right) pz + C_{S,D} + p\,(1+\tau_c)\,C_{S,M} - w_S\,(1-l_S) + \dot{k} + \delta k - r_K k \tag{2.5b}$$

where z denotes the stock of international debt owed by the skilled worker and Z denotes the aggregate stock of international debt in the economy. k denotes the capital stock owned by the skilled worker, whereas K is the aggregate capital stock.[5] This relationship is standard, and incorporates the assumption that the skilled agent also accumulates capital, which

[5]In the macroeconomic equilibrium, $Z = (1-\theta)z$ and $K = (1-\theta)k$.

depreciates at the constant rate δ.

The budget constraint is written from the standpoint of a borrower, although $z < 0$ corresponds to a lender. Whether the equilibrium turns out to be one in which the agent is a debtor or creditor depends upon the relative magnitudes of the rate of time preference and the given world rate of interest, i^*. In either case, a key element of the model is that while the economy has access to the international capital market, it faces a friction in the form of increasing borrowing costs expressed by:

$$i\left(\frac{pZ}{K}\right) = i^* + v\left(a\frac{pZ}{K}\right). \quad v(0) = 0, v' > 0, v'' > 0 \tag{2.6}$$

This equation asserts that the financial friction facing the economy is in the form of a borrowing premium $v(.)$ over the fixed world interest rate. The premium is a positive convex function of its debt relative to its level of development as summarized by its capital stock. There are several alternative ways to formulate this borrowing constraint, but the qualitative implications are essentially identical.[6] The shape of the function, and specifically the parameter, a, reflects the degree of openness of the economy with respect to the international financial market, and the fact that the values of debt is normalized by the capital means that larger, wealthier, economies are less constrained by the financial friction implicit in (2.6). While the individual skilled household takes the borrowing costs as given, the equilibrium borrowing cost is determined by their collective actions.

Analogous to (2.3a)-(2.3c) the optimality conditions with respect to $C_{S,D}$, $C_{S,M}$ and l_S are:

$$\phi C_{S,D}^{\phi\gamma-1} C_{S,M}^{(1-\phi)\gamma} l_U^{\eta\gamma} = \lambda_S \tag{2.7a}$$

$$(1-\phi) C_{S,D}^{\phi\gamma} C_{S,M}^{(1-\phi)\gamma-1} l_S^{\eta\gamma} = p\left(1+\tau_c\right)\lambda_S \tag{2.7b}$$

[6] This formulation of borrowing costs dates back to Bardhan (1967) who expressed it as a function of debt alone. Many modifications, introduced to take account of the country's debt-servicing ability, have since been adopted. See e.g. Senhadji (2003) and Turnovsky and Chattopadhyay (2003) for alternative specifications.

$$\eta C_{S,D}^{\phi\gamma} C_{S,M}^{(1-\phi)\gamma} l_S^{\eta\gamma-1} = \lambda_S w_S \tag{2.7c}$$

and defining C_S analogously to C_U we obtain:

$$C_{S,D} = \phi C_S = \phi \frac{w_S l_S}{\eta} \tag{2.8a}$$

$$p\left(1+\tau_c\right) C_{S,M} = (1-\phi) C_S = (1-\phi)\frac{w_S l_S}{\eta} \tag{2.8b}$$

Performing the optimization with respect to k and z yields the conventional Euler equations

$$(r_K - \delta) = \beta - \frac{\dot{\lambda}_S}{\lambda_S} \tag{2.9a}$$

$$(r_K - \delta) = i\left(\frac{pZ}{K}\right) + \frac{\dot{p}}{p} \tag{2.9b}$$

together with the transversality conditions:

$$\lim_{t\to\infty} \lambda_S(t) k(t) e^{-\beta t} = \lim_{t\to\infty} \lambda_S(t) z(t) e^{-\beta t} = 0 \tag{2.9c}$$

2.3.3 The Government

The government's role is simple. It simply uses its tax revenues to provide a pure public consumption good, G, that impacts households' utility additively, but does not affect their decisions:

$$G = \tau_c p\left[\theta C_{U,M} + (1-\theta) C_{S,M}\right] + \tau_m pm \tag{2.10}$$

2.4 Macroeconomic Equilibrium

To determine the macroeconomic equilibrium, we combine the optimality conditions together with the labor market clearing conditions for the two groups, $N_U + l_U = 1$, $N_S + l_S = 1$, and aggregate market clearing and the current account equilibrium conditions. Specifically, equations (2.1a)-(2.1d), (2.4a), (2.4b), (2.7a), (2.8a), and (2.8b) enable us to solve for $C_{U,D}$, $C_{U,M}$, $C_{S,D}$, $C_{S,M}$, N_S, w_U, w_S, r_K and m in terms of the three dynamic variables K, λ_s, and p, together with the two tariff rates τ_c, τ_m. Thus, generically we may write $X = X(K, \lambda_s, p; \tau_c, \tau_m)$, where $X = C_{U,D}$, etc. and it should be recalled that N_U being determined by (2.4c) is constant and is supplied inelastically over time.

Domestic goods market clearance is described by:

$$F[K, \theta/(1+\eta), (1-\theta)N_S, m] = \theta C_{U,D} + (1-\theta)C_{S,D} + X(p) + \dot{K} + \delta K + G \tag{2.11}$$

where $X(p)$ denotes exports that increase with the relative price of foreign goods and government expenditure, G, is determined by the balanced budget condition, (2.10). Combining the budget constraints for unskilled and skilled workers, (2.2b) and (2.5b), the government budget constraint, (2.10), domestic goods market clearance, (2.11), and the linear homogeneity of the production function, the balance of payments determining the net rate of debt accumulation, expressed in terms of domestic output units is

$$p\dot{Z} = pZi\left(\frac{pZ}{K}\right) + p[\theta C_{U,M} + (1-\theta)C_{S,M} + m] - X(p) \tag{2.12}$$

Thus, rewriting (2.11), the macroeconomic equilibrium can be summarized by

$$\dot{K} = F[K, \theta/(1+\eta), (1-\theta)N_S, m] - \theta C_{U,D} - (1-\theta)C_{S,D} - X(p) - \delta K - G \tag{2.13a}$$

$$\dot{Z} = i\left(\frac{pZ}{K}\right)Z + \theta C_{U,M} + (1-\theta)C_{S,M} + m - \frac{X(p)}{p} \tag{2.13b}$$

$$\frac{\dot{\lambda}_S}{\lambda_S} = \beta - (r_K - \delta) \tag{2.13c}$$

$$\frac{\dot{p}}{p} = (r_K - \delta) - i\left(\frac{pZ}{K}\right) \tag{2.13d}$$

This is a fourth order system in K, Z, λ_S, p with $C_{U,D}$, N_S etc. being expressed in terms of these variables in accordance with the procedure described above. The details of this system, which forms the basis for our simulations of the local dynamics, are discussed in the Appendix. There we note that for our calibrated system it is a saddle point, with K, Z constrained to gradual adjustment, while λ_S, p can respond instantaneously to new information as it comes available.

The focus of our analysis is on the impact of globalization on the labor market and the skill premium. While globalization manifests itself in different ways, we specify trade liberalization in the form of tariff reduction, and financial liberalization in terms of a reduction in the marginal cost of borrowing as parameterized by a. The laying out of the macroeconomic equilibrium illuminates the contrasting channels whereby these impinge on the economy. The tariff rates impact the economy through the short-run efficiency conditions, which then impact the dynamic evolution of the economy via their impact on the relevant demand. By contrast, financial liberalization operates entirely through its impact on the cost of servicing debt. Its immediate effect on the economy operates through its impact on the relative price p and the marginal utility of wealth of skilled workers, λ_s.

2.4.1 Steady-State Equilibrium

The steady-state equilibrium is attained when $\dot{K} = \dot{Z} = \dot{\lambda}_S = \dot{p} = 0$.

$$(\tilde{r}_K - \delta) = i\left(\frac{\tilde{p}\tilde{Z}}{\tilde{K}}\right) = \beta \tag{2.14a}$$

$$\tilde{r}_K = F_K\left(\tilde{K}, \theta/(1+\eta), (1-\theta)\tilde{N}_S, \tilde{m}\right) \tag{2.14b}$$

$$\tilde{w}_U = F_{(\theta N_U)}\left(\tilde{K}, \theta/(1+\eta), (1-\theta)\tilde{N}_S, \tilde{m}\right) \tag{2.14c}$$

$$\tilde{w}_S = F_{(1-\theta)N_S}\left(\tilde{K}, \theta/(1+\eta), (1-\theta)\tilde{N}_S, \tilde{m}\right) \tag{2.14d}$$

$$\tilde{p}\,(1+\tau_m) = F_m\left(\tilde{K}, \theta/(1+\eta), (1-\theta)\tilde{N}_S, \tilde{m}\right) \tag{2.14e}$$

$$\tilde{C}_{U,D} = \phi\frac{\tilde{w}_U}{1+\eta} \tag{2.14f}$$

$$\tilde{C}_{U,M} = \frac{(1-\phi)}{\tilde{p}\,(1+\tau_c)}\frac{\tilde{w}_U}{1+\eta} \tag{2.14g}$$

$$\tilde{N}_U = \frac{1}{1+\eta} \tag{2.14h}$$

$$\phi \tilde{C}_{S,D}^{\phi\gamma-1} \tilde{C}_{S,M}^{(1-\phi)\gamma} \left(1-\tilde{N}_S\right)^{\eta\gamma} = \tilde{\lambda}_s \tag{2.14i}$$

$$\tilde{C}_{S,D} = \frac{\phi \tilde{w}_S \left(1-\tilde{N}_S\right)}{\eta} \tag{2.14j}$$

$$\tilde{C}_{S,M} = \frac{(1-\phi)\tilde{w}_S \left(1-\tilde{N}_S\right)}{\tilde{p}\left(1+\tau_c\right)\eta} \tag{2.14k}$$

$$\tilde{G} = \tau_c p \left[\theta \tilde{C}_{U,M} + (1-\theta)\tilde{C}_{S,M}\right] + \tau_m \tilde{p}\tilde{m} \tag{2.14l}$$

$$F\left[\tilde{K}, \theta/(1+\eta), (1-\theta)\tilde{N}_S, \tilde{m}\right] = \theta \tilde{C}_{U,D} + (1-\theta)\tilde{C}_{S,D} + X(\tilde{p}) + \delta \tilde{K} + \tilde{G} \tag{2.14m}$$

$$\beta \tilde{Z} + \theta \tilde{C}_{U,M} + (1-\theta)\tilde{C}_{S,M} + \tilde{m} = \frac{X(\tilde{p})}{\tilde{p}} \tag{2.14n}$$

These 15 equations determine the steady-state values of $\tilde{K}$, $\tilde{Z}$, $\tilde{p}$, $\tilde{\lambda}_S$, $\tilde{C}_{U,D}$, $\tilde{C}_{U,M}$, $\tilde{N}_U$, $\tilde{C}_{S,D}$, $\tilde{C}_{S,M}$, $\tilde{m}$, $\tilde{N}_S$, $\tilde{w}_U$, $\widetilde{w}_S$, $\tilde{r}_K$ and $\tilde{G}$. The steady-state net return to capital equals the rate of time preference and in turn determines the ratio of debt to capital. Domestic output is either consumed domestically, exported, replaces depreciated capital, or is purchased by the government. Internationally, exports must suffice to finance imports and service the economy's foreign debt.

2.5 Numerical Analysis

To conduct the numerical analysis we need to specify functional forms. In the case of utility, we employ the constant elasticity function, (2.5a), while output is specified by the following production function:

$$F = \left\{\alpha\left(\theta N_U\right)^{\sigma} + (1-\alpha)\left[\omega K^{\rho} + (1-\omega)\left((1-\theta)N_S\right)^{\rho}\right]^{\frac{\sigma}{\rho}}\right\}^{\frac{1-\mu}{\sigma}} m^{\mu} \tag{2.15}$$

This will be recognized as being a variant of the multi-level production function proposed by Krusell et al. (2000).[7] According to (2.15), at the first level, capital and skilled labor are combined via a CES technology having a common elasticity of substitution $(1-\rho)^{-1}$. At the second level, this composite input is combined with unskilled labor using a CES technology having an elasticity of substitution $(1-\sigma)^{-1}$ between unskilled labor, N_U, this composite input, and its components, K, N_S. These three factors are then combined with materials, m, in accordance with a Cobb-Douglas function at the third level. We assume $\sigma > \rho$, which implies capital is more complementary with skilled labor than it is with unskilled labor, as assumed by Krusell et al. (2000) and supported by the empirical evidence.

Dividing (2.1c) by (2.1b) yields the following expression for the skill premium:

$$\frac{w_S}{w_U} = \frac{(1-\alpha)(1-\omega)}{\alpha} \underbrace{(\omega(\frac{K}{(1-\theta)N_S})^{\rho} + (1-\omega))^{\frac{\sigma-\rho}{\rho}}}_{\text{capital-skill complementarity effect}} \overbrace{(\frac{\theta N_U}{(1-\theta)N_S})^{1-\sigma}}^{\text{relative quantity effect}} \tag{2.16}$$

From this equation it is seen that there are two components that affect the skill premium. The first is the 'capital-skill complementarity' effect. Increases in capital tends to disproportionately increase the demand for the skilled labor, thus raising the skill premium. The second is the relative quantity effect which asserts that an increase in the ratio of unskilled labor to skilled labor raises the skill premium as $\sigma < 1$.

The convex borrowing cost function is specified by:

$$i(\frac{pZ}{K}) = i^* + \xi[e^{\frac{apZ}{K}} - 1] \tag{2.17}$$

which has the properties as specified in (2.6) and has been successfully employed elsewhere; see e.g. Chatterjee et al. (2003). Finally, we assume the export function takes a constant

[7] Krusell et al. (2000) assume a three level production function in which capital equipment and skilled labor are combined at the first level, with this composite input combined with unskilled labor at the second level, in both cases by CES production technologies. These three factors are then combined with structures in accordance with a Cobb-Douglas function at the third level.

elasticity form, with κ denoting the elasticity of exports with respect to its relative price:

$$X(p) = X^* p^\kappa \tag{2.18}$$

2.5.1 Calibration

Our benchmark calibration is for a generic economy and we adopt the following strategy. We first specify a set of parameters generally based on consensus estimates obtained from the empirical literature. Having obtained these, we then internally calibrate the remaining parameters that are typically less available, by matching appropriate moments. These include the distributional parameters in the production function, α and ω, and the parameter X^* in the export function.

For parameter values pertaining to utility, we set $\gamma = -1.5$, implying an intertemporal elasticity of substitution equal to 0.4, which is well within the estimated range in the literature as obtained by Guvenen (2006). The elasticity of leisure, $\eta = 1.75$ implies the constant equilibrium leisure of unskilled labor is around 0.64. Taken in conjunction with the steady-state equilibrium leisure rate of skilled workers of 0.74, implies an overall average leisure rate for labor of around 0.67, which is well within the typical range. The exponent on domestic consumption good, $\phi = 0.8$, indicates 20% of total consumption expenditures are on imported goods. We set the rate of time preference, β, to be 0.05. We further set the world real interest rate, i^*, as 0.035. These values of β, i^*, together with the parameterization of the borrowing premium ($a = 0.1$, $\xi = 1$) and the equilibrium level of capital-GDP ratio being around 3 imply that in steady state the economy is a debtor with debt-GDP ratio of 0.447. There is and has been enormous variation in the debt-GDP ratio over time and across countries;[8] in Section 3.5 we consider the scenario in which the economy is a creditor. The depreciation rate, $\delta = 0.06$, is well within the conventional range. For the benchmark case, we set the fraction of unskilled workers, θ, to be 0.7, which is close to the average of

[8]See Lane and Milesi-Ferretti (2007) for detailed discussion of this as well as the World Bank Development Indicators.

the fraction of the population aged 15 years or older that completed secondary education or less for the advanced economies in 2000 estimated by Barro and Lee (2013).[9]. We take the elasticities of substitution in the production function from Krusell et al. (2000), which gives $\sigma = 0.401$ and $\rho = -0.495$. These correspond to skilled labor being a complement to capital, while the composite factor they form is a substitute for unskilled labor. The exponent on materials, $\mu = 0.17$, implies the equilibrium imported materials to GDP ratio is 0.181, which is close to the average values in the developing country data set used by Estevadeordal and Taylor (2013). We set the base tariff on consumption at 22% and the material tariff at 11% (see Turnovsky and Rojas-Vallejos (2018)).[10] Together they generate a tariff revenue of 4.8% of GDP. Elasticity of export to relative price, κ, is set to be 1.4, which is around the average of the estimates in Goldstein and Khan (1978).[11]

Given the parameters chosen above, we calibrate the remaining parameters simultaneously to match skilled labor share as 0.2 and unskilled labor share as 0.45. This yields $\alpha = 0.528$, $\omega = 0.851$ and $X^* = 1.887$.[12] The targeted labor shares by skill level are close to the average of the emerging market and developing economies around 2000 documented by Dao et al. (2017).[13] The benchmark parameter values and key equilibrium quantities are summarized in Table 2.1.

To facilitate our understanding of the diverse mechanisms involved as the economy adjusts over time in response to the globalization, we introduce the various components sequentially. Specifically, we first consider a 10 percentage point reduction in the consumption tariff,

[9]See Table 3 in Barro and Lee (2013)

[10]As Turnovsky and Rojas-Vallejos (2018) discuss these rates were close to the average of low and middle income economies around 1990 prior to the general transition toward trade liberalization.

[11]Goldstein and Khan (1978) estimates the elasticity of export to relative price for eight countries, including Belgium, France, Germany, Italy, Japan, Netherlands, United Kingdom and United states, for the period 1955-1970 using quarterly data. The estimated range in absolute terms is between 0.83-3.29; see Table 3 in Goldstein and Khan (1978).

[12]There are two targeted moments to calibrate three parameters (α, ω and X^*), so there may not be a unique solution. The solution we present is found by the default algorithm in MATLAB.

[13]See Figure 5 in Dao et al. (2017).

followed by a 10 percentage point reduction in the material tariff, and finally, a reduction of the borrowing premium parameter a from 0.1 to 0.06. The impact effects for the base calibration of the debtor economy are reported in Table 2.2, while the steady-state effects are summarized in Table 2.3. The transitions for key variables corresponding to the three modes of liberalization are illustrated in Figure 2.1 and 2.2.

2.6 Reduction in Consumption Tariff

On impact, a 10 percentage point reduction of the consumption tariff increases the demand for the imported consumption good while reducing the demand for the domestic consumption good, the effect of which is to drive up the relative (pre-tariff) price of imported goods by 2.64%. The higher relative price results in a decrease in the imported material good by 3.09% while boosting exports. However, the increase in exports is insufficient to offset the decrease in the demand for the domestic consumption good, leading to a reduction of aggregate demand as reflected in the decline of GDP, albeit slightly, of 0.53%. This imposes downward adjustment pressure on the wages for both types of labor as well as on the return to capital. The higher relative international price increases the interest owed on the debt (denominated in foreign goods), which tends to induce the skilled labor to increase their labor supply. In equilibrium, the working hours of the skilled labor increase slightly by 0.02%. This results in a mild decline in the skill premium of 0.02%. Over time, the reduced aggregate demand lowers the demand for capital, which leads to a short period of rapid decline in capital stock and rise in the return to capital. As the skilled labor gradually repays its debt, the debt level and associated borrowing cost decline. While the burden of servicing debt drops, working hours of the skilled labor is reduced over time.

During the transition the rates of decline of capital stock and debt, that drive the evolution of the economy are moderated eventually leading to an 0.59% reduction in the former and a 2.54% reduction in the latter, while the increase in the (pre-tariff) relative price of imported goods is moderated to 1.99%. The net effect of these intertemporal adjustments is that, over time, the 10 percentage point reduction in consumption tariff reduces the relative price of the imported consumption good to domestic consumption good. Both the unskilled and skilled labor respond by further increasing imported consumption (by 6.23% and 6.00% respectively) while lowering domestic consumption (by 0.53% and 0.75% respectively).

Through changes in the price of imported goods, the reduction in the consumption tariff also impacts the production side. The higher price of imported material raises the cost of production, causing a slight cut in production as manifested by lower input of capital, skilled labor and, imported material. The lower demand for factors of production reduces the wage of both skilled and unskilled labor, albeit slightly, by 0.78% and 0.53%. This in effect reduces the skill premium by 0.25% due to the lower level of capital used in production.

Although the lower demand for labor due to the contraction in production tends to lower their welfare, having access to cheaper imported consumption leads to an overall increase in the intertemporal welfare equivalent to 0.75% of increase in consumption from the initial steady state for the unskilled labor and 0.57% of that for the skilled labor.

2.7 Reduction in Materials Tariff

A reduction in the tariff on materials, by impacting production directly, offers a very different mechanism. On impact, a 10 percentage point reduction in the material tariff reduces the price of imported materials, causing an immediate increase in material of 6.25%. This raises the marginal product of both types of labor and capital, increasing the return to capital and the wage rates by 0.58% and 1.07% for skilled labor and unskilled labor respectively, which in effect lowers the skill premium by 0.49%. The increase in demand for imported material also raises the relative price of imported goods by 4.59%, which tends to shift the consumption composition toward domestic consumption good and increase the value of interest payment of the debt in terms of domestic goods. Heavier burden of servicing the debt also tends to induce skilled labor to increase their working hours, which in equilibrium increases by 0.42%, while those of unskilled worker remains unchanged. Over time, the higher return to capital induces skilled labor to rapidly accumulate capital. To do this, skilled labor issues more debt, which is also reversed after a couple of periods when the return to capital drops sufficiently. The skill premium increases gradually to the new steady state as the capital stock increases and the supply of skilled labor declines.

The increase in capital and the quick reversal in debt accumulation moderate the increase in the price of imported goods, which in steady state increases by 4.93%. In the long run, the sustained 10 percentage point reduction in the materials tariff permanently lowers the cost of imported raw materials, raising the amount of it used in production. This increases the marginal product of all other factors of production, raising the demand for them, which in turn results in an increase in wages for skilled labor of 1.85% and unskilled labor of 1.26%, as well as more capital and skilled labor working hours in production. It implies an increase in the skill premium of 0.58% due to more capital and its complementarity with skilled labor. However, while domestic output increases, GDP drops slightly due to the increase in domestic factors being offset by increased imports of raw materials.

Higher demand for imported materials increases its relative price, which gives both the skilled and unskilled labor an incentive to substitute more domestic consumption for imported consumption. Together with higher level of wages, this leads to an increase in domestic consumption by 1.26% and a decrease in imported consumption by 3.49% for the unskilled labor, and an increase in domestic consumption by 1.78% and a decrease in imported consumption by 2.99% for the skilled labor.

2.8 Financial Liberalization

The immediate effect of a reduction of the borrowing friction from $a = 0.1$ to 0.06 is to reduce the cost of servicing the country's debt, leaving more resources available to finance both domestic and imported consumption as well as raw materials. With the demand for domestic consumption being price inelastic, to induce domestic agents to increase their imports of consumption and raw material their relative price has to drop, doing so by 4.40%. The result of this decline in the relative price is that unskilled workers increase their imports by 4.85%, while that of skilled workers by 5.17%, implying an overall increase in imported consumption of around 5%, while imported materials for production increase by 4.85%. The increase in consumption raises the marginal benefits of leisure, and skilled workers, for whom it is optimal to adjust their leisure time, choose to increase it, thereby reducing their working hours by 0.55%. The reduced supply of skilled labor and more imported material good in production lead to higher marginal product of the skilled labor, increasing their wage by 1.29%. It also increases the skill premium by 0.48% due to the increase in the ratio of capital to skilled labor and the reduction in the ratio of skilled to unskilled labor.

The subsequent transitional effects on skilled labor as the economy adjusts following the initial reduction in borrowing costs contrast sharply with those occurring on impact. Over time, reduced borrowing costs give the skilled labor an incentive to accumulate capital rapidly through issuing new debt. The accumulation of the debt level increases the borrowing cost and leads to a growing burden of interest payment of the debt. As a response, the skilled labor gradually reduces the consumption spending, slows down the accumulation of capital and increases labor supply in order to meet the growing debt payment. While the increased supply of skilled labor tends to raise the marginal product of unskilled labor, and thus their wage, it tends to lower that of the skilled labor, which drives down the skill premium to the point even below the initial steady state level. As a result, the consumption spending on the domestic good from the unskilled labor declines at a slower rate than that from the skilled labor (after a short period of increase). The initial sharp rise of capital stock enables a short period of rapid growth of output. As the investment declines sufficiently to the point of not being able to cover the depreciation, capital stock starts to decline, which puts downward adjustment pressure on the wages and the output over time.

In the long run, reducing the borrowing costs by reducing the parameter a in the borrowing premium from 0.1 to 0.06, causes substantial changes to both the demand and production sides of the economy. The reduced external borrowing friction enables the economy to accumulate higher level of capital financed through debt; it increases the capital stock by 1.16% and raises debt-GDP ratio significantly by 67.88%. The much higher level of debt and associated interest payment significantly suppress the demand for consumption of the skilled labor; it decreases the domestic consumption and imported consumption by 4.05% and 6.84%

respectively. As debt is denominated in imported goods, higher interest payment for debt drives up the relative price of imported goods by 2.99%, which is manifested by a decline in imported consumption and imported material. To service the increased debt, skilled labor has to also increase working hours by 3.21%. Although more capital accumulated tends to boost output and raise the demand for all other factors in production, the large increase in skilled labor supply, together with the drop in imported material, actually reduces the wage for skilled labor by 2.96%, and this is in sharp contrast with the increase in the wage for unskilled labor by 0.02%, which in effect lowers the skill premium by 2.97%. Carrying the burden of servicing the growing debt, the skilled labor is worse off in the long run, as manifested by lower consumption and more working hours. However, this is outweighed by the short run benefit due to lower borrowing cost, leading to an overall increase in the intertemporal welfare of the skilled labor equivalent to 0.21% of increase in consumption from the initial steady state.

2.9 Conclusion

In this paper, we employ a dynamic general equilibrium model with two types of labor to jointly assess the effects of consumption tariff reduction, materials tariff reduction and financial liberalization on the skill premium, based on the calibration to a generic debtor economy. Our simulation results highlight the sharply contrasting effects from these various forms of globalization and the diverse mechanisms involved as the economy adjusts over time. In particular, while both forms of the tariffs reduction reduces the skill premium upon impact, the reduction in materials tariff increases the skill premium over time whereas the reduction in consumption tariff further reduces the skill premium along the transitional path due to their opposing effects on the growth of capital stock. In contrast, financial liberalization increases the skill premium on impact and the transitional dynamics of the skill premium later on exhibits a hump-shaped evolution driven by the two countervailing forces of growing capital stock and rising skilled labor supply.

Tables

Table 2.1: **Benchmark Calibration and Equilibrium**

A. The Benchmark Economy	
Preference parameters:	$\gamma = -1.5$, $\eta = 1.75$, $\phi = 0.8$, $\beta = 0.05$
Production parameters:	$\sigma = 0.401$, $\rho = -0.495$, $\alpha = 0.528$, $\omega = 0.851$, $\mu = 0.17$
Depreciation rate:	$\delta = 0.06$
World interest rate:	$i^* = 0.035$
Premium on borrowing:	$a = 0.1$
Weight on the premium:	$\xi = 1$
Tariffs:	$\tau_c = 0.22$, $\tau_m = 0.11$
Fraction of unskilled workers:	$\theta = 0.7$
Export parameters:	$\kappa = 1.4$, $X^* = 1.887$
B.Key Equilibrium Quantities	
Capital to GDP ratio:	3.001
Debt to GDP ratio:	0.447
Tariff revenues to GDP ratio:	0.048
Aggregate labor share of income:	0.650
Skilled labor share of income:	0.200
Unskilled labor share of income:	0.450
Skill premium:	1.458
Imported materials to GDP ratio:	0.181
Trade balance to GDP ratio:	0.022
Stable eigenvalues:	-0.184 -0.030

Table 2.2: **Key On-Impact Responses to Tariffs Reduction and Financial Liberalization (Benchmark Case)**

A. Aggregate quantities									
	GDP	$\dot{K}$	**K/GDP**	**p**	$\dot{Z}$	**pZ/GDP**	**m**	**EXP/GDP**	**TB/GDP**
Initial Eq $\tau_c = 0.22$, $\tau_m = 0.11$, $a = 0.1$	0.3175	0.0000	3.0010	0.1270	0.0000	0.4468	0.4520	0.3307	0.0223
Reduce τ_c by 0.10	0.3158	-0.0011	3.0169	0.1304	-0.0045	0.4610	0.4381	0.3448	0.0251
% change	(-0.53%)		(0.53%)	(2.64%)		(3.19%)	(-3.09%)	(4.27%)	(12.37%)
Reduce τ_m by 0.10	0.3153	0.0014	3.0221	0.1328	0.0025	0.4706	0.4803	0.3546	0.0228
% change	(-0.70%)		(0.71%)	(4.59%)		(5.33%)	(6.25%)	(7.23%)	(2.04%)
Reduce a by 0.04	0.3202	0.0071	2.9751	0.1214	0.0454	0.4234	0.4739	0.3078	0.0013
% change	(0.87%)		(-0.86%)	(-4.40%)		(-5.23%)	(4.85%)	(-6.92%)	(-94.40%)
B. Impact on labor									
	Nu	**Ns**	**Wu**	**Ws**	**Ws/Wu**	**Cud**	**Cum**	**Csd**	**Csm**
Initial Eq $\tau_c = 0.22$, $\tau_m = 0.11$, $a = 0.1$	0.3636	0.2586	0.5613	0.8186	1.4584	0.1633	0.2634	0.2774	0.4476
Reduce τ_c by 0.10	0.3636	0.2586	0.5583	0.8140	1.4581	0.1624	0.2780	0.2759	0.4723
% change	(0.00%)	(0.02%)	(-0.53%)	(-0.55%)	(-0.02%)	(-0.53%)	(5.56%)	(-0.56%)	(5.53%)
Reduce τ_m by 0.10	0.3636	0.2597	0.5673	0.8233	1.4513	0.1650	0.2546	0.2786	0.4298
% change	(0.00%)	(0.42%)	(1.07%)	(0.58%)	(-0.49%)	(1.07%)	(-3.36%)	(0.43%)	(-3.97%)
Reduce a by 0.04	0.3636	0.2571	0.5658	0.8291	1.4654	0.1646	0.2762	0.2814	0.4707
% change	(0.00%)	(-0.55%)	(0.81%)	(1.29%)	(0.48%)	(0.81%)	(4.85%)	(1.43%)	(5.17%)

Table 2.3: **Key Steady-State Responses to Tariffs Reduction and Financial Liberalization (Benchmark Case)**

A. Aggregate quantities									
	GDP	**K**	**K/GDP**	**p**	**Z**	**pZ/GDP**	**m**	**EXP/GDP**	**TB/GDP**
Initial Eq $\tau_c = 0.22$, $\tau_m = 0.11$, $a = 0.1$	0.3175	0.9528	3.0010	0.1270	1.1168	0.4468	0.4520	0.3307	0.0223
Reduce τ_c by 0.10	0.3155	0.9471	3.0017	0.1296	1.0884	0.4469	0.4405	0.3421	0.0223
% change	(-0.62%)	(-0.59%)	(0.02%)	(1.99%)	(-2.54%)	(0.02%)	(-2.56%)	(3.44%)	(0.02%)
Reduce τ_m by 0.10	0.3164	0.9662	3.0539	0.1333	1.0793	0.4547	0.4804	0.3550	0.0227
% change	(-0.35%)	(1.41%)	(1.77%)	(4.93%)	(-3.35%)	(1.77%)	(6.28%)	(7.34%)	(1.77%)
Reduce a by 0.04	0.3189	0.9638	3.0228	0.1308	1.8282	0.7501	0.4408	0.3431	0.0375
% change	(0.43%)	(1.16%)	(0.73%)	(2.99%)	(63.70%)	(67.88%)	(-2.49%)	(3.77%)	(67.88%)
B. Impact on labor									
	Nu	**Ns**	**Wu**	**Ws**	**Ws/Wu**	**Cud**	**Cum**	**Csd**	**Csm**
Initial Eq $\tau_c = 0.22$, $\tau_m = 0.11$, $a = 0.1$	0.3636	0.2586	0.5613	0.8186	1.4584	0.1633	0.2634	0.2774	0.4476
Reduce τ_c by 0.10	0.3636	0.2584	0.5583	0.8122	1.4548	0.1624	0.2798	0.2754	0.4744
% change	(0.00%)	(-0.07%)	(-0.53%)	(-0.78%)	(-0.25%)	(-0.53%)	(6.23%)	(-0.75%)	(6.00%)
Reduce τ_m by 0.10	0.3636	0.2590	0.5683	0.8337	1.4669	0.1653	0.2542	0.2824	0.4342
% change	(0.00%)	(0.17%)	(1.26%)	(1.85%)	(0.58%)	(1.26%)	(-3.49%)	(1.78%)	(-2.99%)
Reduce a by 0.04	0.3636	0.2669	0.5614	0.7944	1.4151	0.1633	0.2558	0.2662	0.4170
% change	(0.00%)	(3.21%)	(0.02%)	(-2.96%)	(-2.97%)	(0.02%)	(-2.89%)	(-4.05%)	(-6.84%)
C. Intertemporal welfare effects (in terms of equivalent percentage change in consumption)									
	Unskilled	**Skilled**							
Reduce τ_c by 0.10	0.75%	0.57%							
Reduce τ_m by 0.10	0.17%	-0.14%							
Reduce a by 0.04	0.66%	0.21%							

Figures

Figure 2.1: **Dynamics of Tariffs Reduction and Financial Liberalization for the Benchmark Economy**

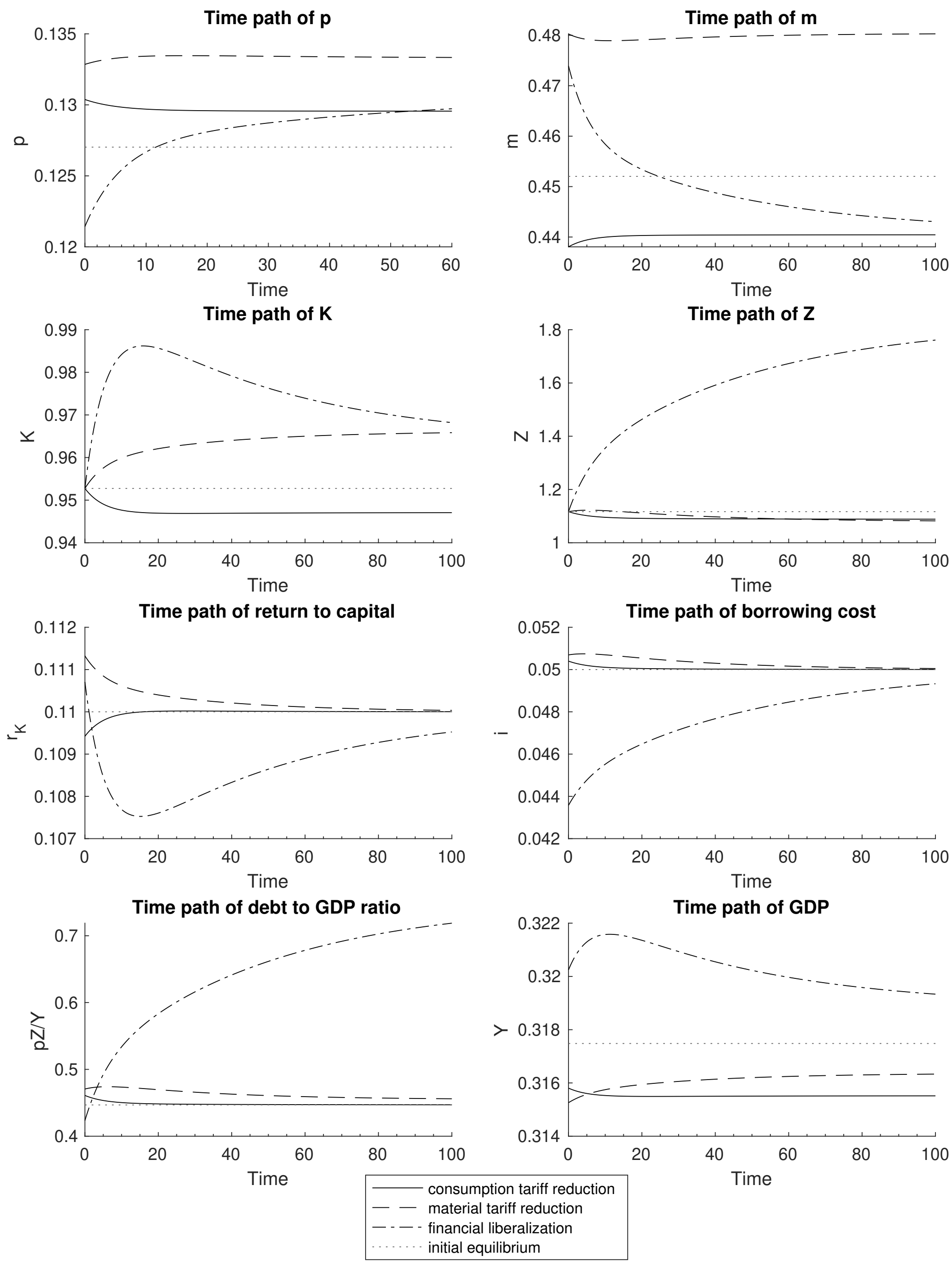
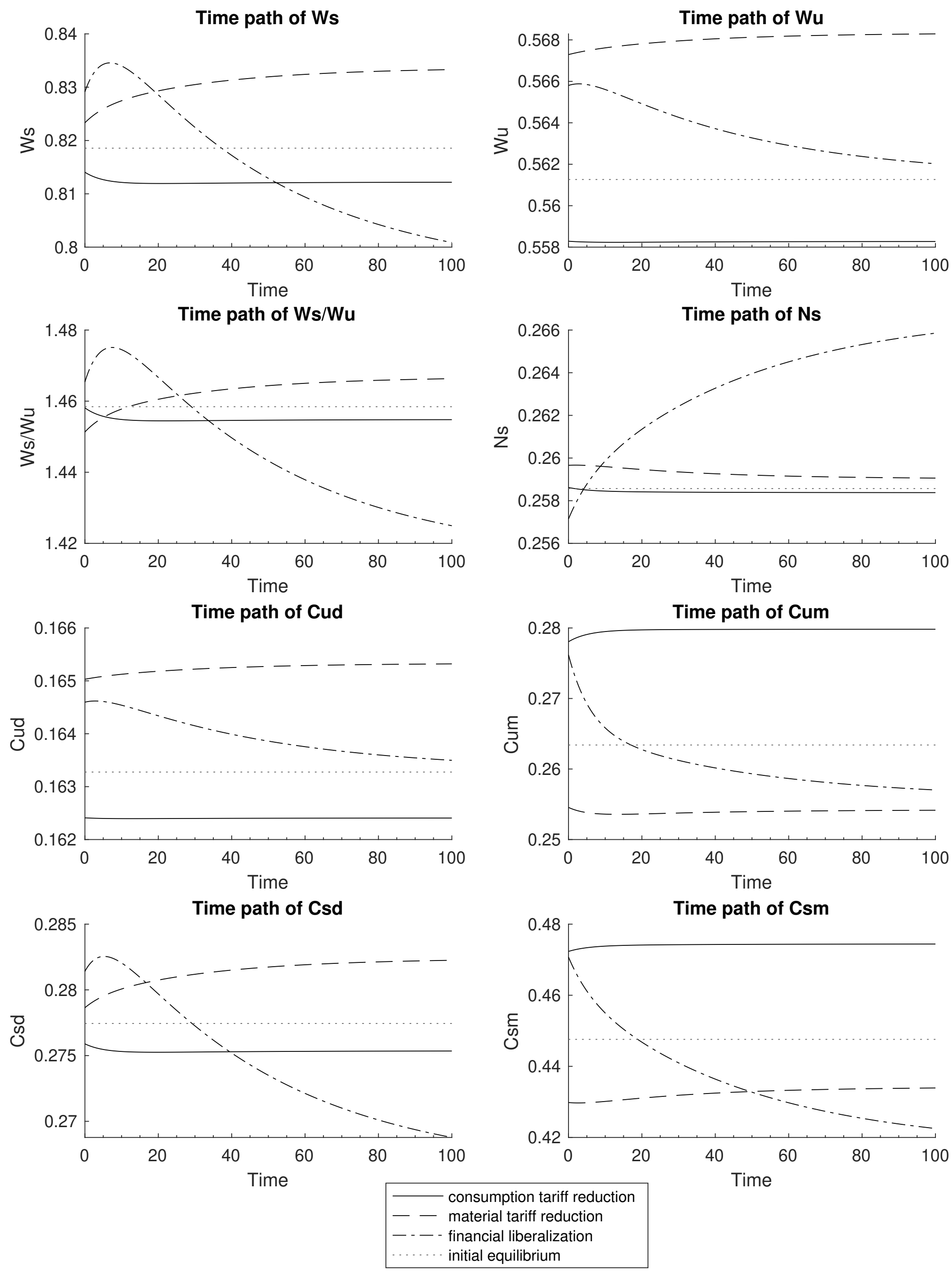


Figure 2.2: **Dynamics of Tariffs Reduction and Financial Liberalization for the Benchmark Economy (Continued)**



Chapter 3

EXTENSIONS[1]

3.1 Introduction

This chapter contains several natural extensions to Chapter 2. We start by dissecting the mechanism driving the dynamics of the skill premium over time. By decomposing the log change of skill premium into the capital-skill complementarity (CSC) component and relative quantity (RQ) component, we show that the evolution of the skill premium for the two forms of tariffs reduction are almost entirely driven by the dynamics of the CSC component. For financial liberalization, the CSC component initially drives the rise in the skill premium, while after around 30 periods the RQ component starts to dominate the CSC component, and in the long run the RQ component accounts for around two third of the change in the skill premium.

We then conduct an extensive sensitivity analysis on the key parameters in the benchmark model. Although most estimates of the two elasticities of substitution in the production function, σ and ρ, in the literature support the assumption of capital-skill complementarity (i.e. $\sigma > \rho$), there exists quite a variation of the point estimates of these elasticities. So we construct a grid of σ and ρ covering most of the range of the estimates in the literature. For each combination in the grid, we obtain the effects of the three modes of globalization on the skill premium. For the on-impact effects, the magnitudes are negligible for consumption tariff reduction across the grid. The effects of materials tariff reduction are relatively robust, while those for the financial liberalization are sensitive to the changes, with the effect being strongest when the capital-skill complementarity effect is the largest. For the steady-state responses, the effects remain qualitatively the same across the grid for all three modes of

[1]This chapter is a joint work with Stephen Turnovsky from the University of Washington.

globalization. We then consider a set of other structural parameters that may vary to a great extent across countries at different stages of development. These include the relative importance of domestic consumption good, ϕ, the fraction of unskilled labor, θ, and the export elasticity to relative price, κ. Across all three modes of globalization, the long-run qualitative effects on the skill premium remain as in the benchmark case.

In light of the empirical findings in Raveh and Reshef (2016) that shows the composition of imported goods may affect their complementarity with labor across different skills, we explore the property of the model in a production setting where imported material is also more complementary with the skilled labor than it is with the unskilled labor. In this case, the dynamic nature of our model enables us to identify two separate channels through which a reduction in the materials tariff increases the skill premium. The first is through the *direct* 'material-skill complementarity' effect which has an immediate impact on the skill premium. The second is through the *indirect* effect via the accumulation of capital which only operates along the transitional path and in the long run. With the additional direct effect in this case, reduction in materials tariff increases the skill premium by 0.55% upon impact, whereas it decreases the skill premium by 0.49% in the benchmark case.

Lastly, we consider the scenario in which the economy is a creditor instead of a debtor as in the benchmark case. This leads to dramatic changes to the impact effects of the tariffs reduction and the long-run effects of financial liberalization on the skill premium. Although tariffs reduction, for both debtor and creditor economies, tends to increase the relative price of imported goods upon impact, it results in higher interest payment received in the creditor economy which induces the skilled labor to cut working hours, whereas it tends to increase the working hours due to heavier burden of servicing the debt in the debtor economy. This in turn generates different effects on the skill premium. For financial liberalization, while it attracts foreign investment and over time tends to raise the level of capital and the working hours of the skilled labor for the debtor economy, it diverts the resources to invest abroad and lowers the domestic capital stock and working hours of the skilled labor for the creditor economy, and consequently leads to sharply contrasting dynamics of the skill premium.

3.2 Dissecting the Mechanism

From equation (2.16), it is seen that skill premium is affected by both the capital-skill complementarity (CSC) effect and relative quantity (RQ) effect. To better understand the mechanisms driving the dynamics of the skill premium over time, we take log change on both sides of equation (2.16), yielding the following equation:

$$\Delta log(\frac{w_S}{w_U}) \quad = \quad \underbrace{(\sigma-\rho)\Delta log[(\omega(\frac{K}{(1-\theta)N_S})^{\rho}+(1-\omega))^{\frac{1}{\rho}}]}_{\text{CSC component}} \quad + \quad \underbrace{(1-\sigma)\Delta log(\frac{\theta N_U}{(1-\theta)N_S})}_{\text{RQ component}} \tag{3.1}$$

which states that the log change of the skill premium is equal to the sum of the CSC component and the RQ component. The dynamics of the log change of the skill premium from the initial steady state, along with its two components, are shown in Figure 3.1. We see clearly that the dynamics of the skill premium for the two forms of tariffs reduction are almost entirely driven by the dynamics of the CSC component, which reflects mainly the changes in capital stock over time. For financial liberalization, however, the relationship is more subtle. The CSC component initially drives the rise in the skill premium, reflecting the rapid accumulation of capital financed through foreign debt. After 10 period or so, the skill premium reaches its peak and starts to decline, which is accounted for by both the decline in the RQ component and the slowdown in the rise of the CSC component. After around 30 periods, driven by the large increase in the skilled labor supply due to the rising debt burden, the RQ component starts to dominate the CSC component and the log change of skill premium turns to be negative. In the long run, the RQ component accounts for around 63% of the decline in the skill premium, with the rest 37% accounted for by the CSC component.

3.3 Sensitivity Analysis

3.3.1 Production Elasticities

A key assumption in our production function, which plays an important role to the effects on the skill premium, is that capital is more complementary with skilled labor than unskilled labor, and we take the elasticities of substitution estimated in Krusell et al. (2000) as our benchmark calibration. Although most estimates in the literature, to the best of our knowledge, support the assumption of capital-skill complementarity, there exists quite a variation of the point estimates of the elasticities of substitution; see Table 3.1 for a summary of the estimates from recent literature. In this section, we examine how the effects from different forms of globalization on the skill premium change quantitatively as these elasticities vary. To do so, we construct a grid of σ and ρ that covers most of the range of the estimates in the literature; the range of σ in our grid is from 0.2 to 0.85 and that of ρ is from -0.6 to 0.2. For each combination of σ and ρ in the grid we recalibrate α, ω and X^* to match the targeted labor shares by skill as in the benchmark calibration, since variations in the elasticities may lead to substantial change in the labor shares. We then obtain both the on-impact and steady-state effects from different modes of globalization on the skill premium for each combination of σ and ρ; the results are reported in Table 3.2 and 3.3 (with the effects of benchmark calibration shown in bold).

For the on-impact effects, the magnitudes are negligible for consumption tariff reduction across the grid. The effects of materials tariff reduction are relatively robust, ranging from -0.33% to -0.52%, while those of financial liberalization on the skill premium is sensitive to the changes. The effect is the weakest, 0.02%, when $\sigma = \rho = 0.2$ at the top right corner, which implies there is no capital-skill complementarity. It becomes the strongest when the CSC effect is the largest at the bottom left corner where $\sigma = 0.85$ and $\rho = -0.6$. Turning to the steady-state responses, the effects remain qualitatively the same across the grid for all three modes of globalization. As the long-run effects on the skill premium from the two forms of tariffs reduction are almost entirely driven by the CSC component, it is no surprising that the effects are the weakest (-0.04% for consumption tariff reduction and 0.09% for material tariff reduction) when $\sigma = \rho = 0.2$, and the strongest (-0.53% for consumption tariff reduction and 1.25% for material tariff reduction) when $\sigma = 0.85$ and $\rho = -0.6$. For the financial liberalization, however, both the CSC component and the RQ component account for a substantial fraction of the long-run changes in skill premium for the benchmark calibration. As ρ increases, it tends to decrease the CSC effect, leading to a smaller overall effect on the skill premium. As σ increases, although it tends to increase the CSC effect, it significantly reduces the RQ effect, also weakening the overall effect. Therefore, the weakest effect on the skill premium, -1.53%, occurs when $\rho = 0.2$ and $\sigma = 0.85$ at the bottom right corner of the grid, while the strongest effect, -3.46%, occurs when $\rho = -0.6$ and $\sigma = 0.2$ at the top left corner.

3.3.2 Other Structural Parameters

As our benchmark calibration is generic and applies to countries at varying stages of development, we subject key parameters to sensitivity analysis in this section to characterize the potentially differential impacts from globalization on more or less developed economies. We consider three parameters that may vary to a great extent across countries: (i) a decrease in the relative importance of domestic consumption good, ϕ; (ii) an increase in the fraction of unskilled labor, θ; (iii) a variation in the export elasticity to relative price, κ. Table 3.4 summarises the results.

Across all three measures of globalization, the qualitative effects on the skill premium remain as the benchmark case in the long run. Quantitatively, the effects of globalization are all affected though by the variations in these parameters we consider. In particular, an increase in consumption openness, as reflected by a decrease in the relative importance of domestic consumption good, ϕ, strengthens the impact of the two tariff reductions on the skill premium while attenuates that of financial liberalization. Larger expenditure in imported consumption good increases the reaction of p caused by the increase in demand for the imported consumption good after a reduction in consumption tariff. Larger increase in p leads to greater drop in imported material, and it in turn results in larger reduction in the capital stock, which contributes to the larger decrease in the skill premium. Larger expenditure in imported consumption good implies a relatively smaller role for imported material and interest payment of debt in the balance of payment. In the case of a material tariff reduction, this results in a smaller increase in p, which in turn leads to larger increase in imported material and capital stock, thus greater increase in the skill premium. For the case of financial liberalization, less increase in p results in less drop in material and larger increase in capital, which implies less decrease in the skill premium.

An increase in the fraction of unskilled labor, θ, characteristic of many developing economies, weakens the propensity of the reduction in material tariff to increase the skill premium. Higher fraction of unskilled labor also attenuates the impact of financial liberalization. The effect of the reduction in consumption tariff is relatively robust to the change in θ.

The export elasticity to relative price, κ, affects the responsiveness of the relative price p for a given change in the demand for imported goods or the interest payment of debt. In particular, the higher κ is the less change in p is required to reach the balance of payment equilibrium. This is apparent in Table 3.4 that the absolute value of percentage change in p drops as κ increases in all three forms of globalization. In the case of a reduction in consumption tariff, less increase in p due to the increase in demand for imported consumption good implies less reduction in imported material, thus imposing less negative impact on the production. This leads to less drop in the level of capital stock and weakens the impact on the skill premium. Turning to the case of a reduction in material tariff, less increase in p leads to higher increase in imported material and capital stock, which increases the impact on the skill premium. For the case of financial liberalization, anticipating there is less increase in p, the skilled labor increases the level of debt by a greater extent, which leads to greater increase in the burden of debt interest payment in the long run. This in turn results in larger increase in the skilled labor supply, which strengthens the propensity to decrease the skill premium from financial liberalization in the long run.

3.4 Production with Material-Skill Complementarity (MS Case)

In this section, we experiment different ways in which material interacts with the rest of factors in the production function and compare their corresponding effects. The idea is based on the empirical findings of Raveh and Reshef (2016), in which the authors empirically test the effect of capital imports on the skill premium using a sample of developing countries, and find that while imports of R&D-intensive capital equipment raise the skill premium, imports of less innovative capital equipment lowers the skill premium. To the extent that the composition of material goods may affect its complementarity with labor by different skills, we explore the property of the model in a production setting where material is more complementary with the skilled labor, whereas there is no material-skill complementarity effect in the benchmark setting. In this case, output is specified by the following production function:

$$F = \left\{ \alpha \left(\theta N_U\right)^{\sigma} + (1-\alpha) \left[\omega_1 K^{\rho} + \omega_2 m^{\rho} + (1-\omega_1-\omega_2)\left((1-\theta) N_S\right)^{\rho}\right]^{\frac{\sigma}{\rho}} \right\}^{\frac{1}{\sigma}} \tag{3.2}$$

According to (3.2), at the first level of the production function, capital, skilled labor, and imported raw materials are combined via a CES technology having a common elasticity of substitution $(1-\rho)^{-1}$. At the second level, this composite input is combined with unskilled labor using a CES technology having an elasticity of substitution $(1-\sigma)^{-1}$ between unskilled labor, N_U, this composite input, and its components, K, m, N_S. We assume $\sigma > \rho$, which implies capital and imported material are both more complementary with skilled labor than they are with unskilled labor. For this case, imported material enters the production function with a similar role to capital in terms of the elasticity of substitutions with skilled and unskilled labor.

Dividing (2.1c) by (2.1b) yields the following expression for the skill premium:

$$\frac{w_S}{w_U} = \frac{(1-\alpha)(1-\omega_1-\omega_2)}{\alpha} \underbrace{(\omega_1(\frac{K}{(1-\theta)N_S})^\rho + \omega_2(\frac{m}{(1-\theta)N_S})^\rho + (1-\omega_1-\omega_2))^{\frac{\sigma-\rho}{\rho}}}_{\text{capital- and material-skill complementarity effects}} \overbrace{(\frac{\theta N_U}{(1-\theta)N_S})^{1-\sigma}}^{\text{relative quantity effect}}$$

There are three components that affect the skill premium. The first two components are the 'capital-skill complementarity' effect and the 'material-skill complementarity' effect. The third is the relative quantity effect.

We choose the same values as in the benchmark case for the parameters which are externally calibrated then. We then internally calibrate α, ω_1, ω_2 and X^* to match capital-GDP ratio as 3, skilled labor share as 0.2 and unskilled labor share as 0.45. This yields $\alpha = 0.444$, $\omega_1 = 0.626$, $\omega_2 = 0.262$ and $X^* = 1.878$. The parameter values and key equilibrium quantities are summarized in Table 3.5. The similarity of the structural parameters (except for the production parameters) and key equilibrium quantities between this case and the benchmark case enables us to contrast the difference in the quantitative effects due to different production settings.

The comparison of key on-impact responses and steady-state responses are summarized in Table 3.6 and 3.7 respectively. Qualitatively, the effects of globalization on the skill premium are the same across the benchmark case and the MS case except for the on-impact effect after material tariff reduction. In the benchmark case, material tariff reduction decreases the skill premium on impact whereas it increases the skill premium in the MS case. This is not surprising, since there is 'material-skill complementarity' effect in the latter case; increases in imported material raises the skill premium upon impact. The dynamic nature of our model thus enables us to identify two separate channels through which a reduction in the materials tariff increases the skill premium in the current production setting. The first is through the *direct* 'material-skill complementarity' effect which has an immediate impact on the skill premium, since imported materials increases upon impact. The second is through the *indirect* effect via the accumulation of capital. The mechanism at play here is that the lower price of material stimulates growth, with the resulting increase in capital disproportionately raising the demand for skilled labor due to the 'capital-skill complementarity' effect. This second channel does not hinge on the 'material-skill complementarity' assumption, but operates only in the medium term (along the transition to the new steady state) and in the long run; material tariff reduction increases the skill premium in the long run across both the benchmark case and the MS case. Quantitatively, our simulation shows that the long-run impact of globalization on the skill premium across all three modes are larger under the MS case.

3.5 Creditor Economy

In this section, we consider the scenario in which the economy is a creditor. This requires $\beta < i^*$, and we set $\beta = 0.35$ and $i^* = 0.05$. The values of the rest of the the parameters are chosen as the same with the benchmark case. Table 3.8 summarises the parameter values and the key equilibrium quantities. In equilibrium, the ratio of the foreign bonds owned by the creditor economy to its GDP is 51.7%. The key on-impact and steady-state responses to the three modes of globalization for the creditor economy are reported in Table 3.9 and 3.10 respectively. The transitions for key variables are illustrated in Figure 3.2 and 3.3.

3.5.1 Reduction in Consumption Tariff

For the consumption tariff reduction, as with the debtor economy, it increases the demand for imported consumption on impact, which in turn drives up the relative price of imported goods. However, for the creditor economy, higher relative price implies larger values of foreign bonds and interest payment received in terms of domestic goods, which induces the skilled labor to increase leisure and reduce working hours, which raises the skill premium by 0.19% on impact. In contrast, the consumption tariff reduction decreases the skill premium for the debtor economy by 0.02% on impact. Higher value of the foreign bonds reduces their return, which gives an incentive for the skilled labor to sell the foreign bonds over time to finance their consumption. As the level of foreign bonds drops, so is the interest payment received, which induces the skilled labor to gradually raise the working hours. This, together with the drop in capital, lowers the skill premium over time to approach the new steady state, which is 0.26% smaller than the initial level, and is similar to the magnitude of the final drop in percentage terms for the debtor economy.

3.5.2 Reduction in Materials Tariff

Turning to the case of material tariff reduction, it increases the demand for imported materials and drives up the relative price of imported goods, just as the debtor economy. However, for the creditor economy, higher relative price again increases the interest payment received of the foreign bonds in terms of domestic goods. Although higher demand for labor, driven by the larger amount of imported materials used in production, tends to increase the working hours of the skilled labor, higher interest payment received tends to lower the supply of the skilled labor, thus having the opposite effect on the working hours. The two countervailing forces in equilibrium leads to a slight increase in the working hours of the skilled labor by 0.07%, and thus only a mild decrease in the skill premium by 0.08% on impact, while the material tariff reduction decreases the skill premium by 0.49% for the debtor economy. More imported materials used in production drives up the return to capital and induces the skilled labor to sell the foreign bonds to finance the accumulation of capital over time. As capital increases, it gradually raises the skill premium through the 'capital-skill complementarity effect'. In the final steady state, skill premium is increased by 0.49%, which is comparable to the 0.58% of increase for the debtor economy.

3.5.3 Financial Liberalization

The effects of financial liberalization on the creditor economy contrast sharply with those on the debtor economy both in the medium run and the long run. Specifically, the reduction of the lending friction immediately increases the return to the foreign bonds, and thus raising the interest payment received by the skilled labor, which induces them to cut the working hours by 0.61%. Lower skilled labor supply increases the skill premium by 0.66% on impact. The higher return to the foreign bonds also induces the skilled labor to invest more in the foreign bonds (denominated in foreign goods), which raises the demand for foreign goods, and in turn imposes upward pressure on the relative price of the foreign goods to reach the balance of payment equilibrium. In equilibrium, the relative price increases by 2.96% on impact for the creditor economy, whereas it decreases by 4.40% for the debtor economy. Higher relative price reduces the demand for imported consumption and materials. Less imported materials used in production tend to decrease the GDP and the return to capital.

Over time, lower return to capital induces the skilled labor to cut investment in domestic physical capital in order to raise the investment in foreign bonds. This leads to a period of rapid drop in physical capital, which is also reversed when the return to capital increases sufficiently. The accumulation of foreign bonds gradually increases the interest payment received by the skilled labor, which reduces the relative price of foreign goods and induces the skilled labor to further cut working hours. Although the skill premium declines for a short period due to the initial rapid drop in capital stock, the trend is reversed as the skilled labor supply decreases gradually. In the long run, capital stock and GDP drops by 0.77% and 0.23% for the creditor economy, while those increase by 1.16% and 0.43% for the debtor economy. The skill premium increases by 2.17%, whereas it decreases by 2.97% for the debtor economy.

The skilled labor in the creditor economy are made better off in the long run by the financial liberalization, as manifested by higher consumption and lower working hours. This results in an increase in the intertemporal welfare equivalent to 1.72% of increase in consumption from the initial steady state, which is much larger than the 0.21% of increase for the debtor economy. For the unskilled labor, although they are also better off in the long run, the short-run decrease in consumption leads to an overall reduction in their intertemporal welfare equivalent to 0.24% of decrease in consumption, which is in sharp contrast to the 0.66% of increase for the debtor economy.

3.6 Conclusion

In this chapter, we conduct several extensions to Chapter 2 and the results highlight the complexity of the issue when one assesses the effects of globalization on the skill premium. Although the qualitative nature of the responses to the two forms of tariffs reduction and financial liberalization in the benchmark model are fairly robust with respect to variations in key structural parameters, including the elasticities of substitution in the production function, the simulation indicates that the impact effect of material tariff reduction changes dramatically if there is material-skill complementarity while the long-run effect remain similar. It also leads to very different impact effects of the tariffs reduction and long-run effects of financial liberalization if the external financial position of the economy changes from a debtor to a creditor. Our results in this chapter thus call for the considerations of the composition of the imported raw materials and the external financial position of the economy when evaluating the effects of globalization on the skill premium over time.

Tables

Table 3.1: **Summary of Key Empirical Estimates of Production Elasticities**

σ	ρ	**Source**	**Estimation methodology**	**Period coverage**	**Country**	**Note**
0.401	-0.495	Krusell et al. (2000); Table 1	two-step SPML	1963-1992	US	
(0.234)	(0.048)					
0.546	0.205	Duffy et al. (2004); Table 1	NLLS	1965-1990	73 developed and less developed countries	
(0.068)	(0.159)					
0.239	0.522	Duffy et al. (2004); Table 1	NLLS with FE	1965-1990	73 developed and less developed countries	
(0.076)	(1.017)					
0.787	0.456	Duffy et al. (2004); Table 1	GMM-IV with FE	1965-1990	73 developed and less developed countries	
(0.295)	(2.470)					
0.899	-0.567	Polgreen and Silos (2008); Table 1	Bayesian inference	1963-1992	US	equipment price series from NIPA
(0.036)	(0.052)					
0.917	0.010	Polgreen and Silos (2008); Table 1	Bayesian inference	1963-1992	US	equipment price series from Greenwood et al. (1997)
(0.061)	(0.074)					
0.415	-0.324	Maliar et al. (2020); Table 1	two-step SPML	1963-2017	US	
(0.011)	(0.022)					
0.431	-0.309	Ohanian et al. (2021); Table 5.2	two-step SPML	1963-2019	US	
(0.012)	(0.026)					

Standard errors are in parentheses.

Table 3.2: **Sensitivity Analysis for On-Impact Responses of Skill Premium (in % Change from Initial Steady State; Benchmark Case)**

	ρ=-0.6	ρ=-0.495	ρ=-0.4	ρ=-0.3	ρ=-0.2	ρ=-0.1	ρ=0.01	ρ=0.1	ρ=0.2
A. Reduce τ_c by 0.10									
σ=0.2	-0.02%	-0.01%	-0.01%	0.00%	0.00%	0.01%	0.02%	0.03%	0.04%
σ=0.3	-0.02%	-0.02%	-0.01%	-0.01%	0.00%	0.01%	0.02%	0.02%	0.03%
σ=0.401	-0.03%	**-0.02%**	-0.02%	-0.01%	0.00%	0.00%	0.01%	0.02%	0.03%
σ=0.5	-0.03%	-0.02%	-0.02%	-0.01%	-0.01%	0.00%	0.01%	0.02%	0.02%
σ=0.6	-0.03%	-0.03%	-0.02%	-0.02%	-0.01%	0.00%	0.01%	0.01%	0.02%
σ=0.7	-0.04%	-0.03%	-0.02%	-0.02%	-0.01%	-0.01%	0.00%	0.01%	0.02%
σ=0.85	-0.04%	-0.03%	-0.03%	-0.02%	-0.02%	-0.01%	0.00%	0.01%	0.01%
B. Reduce τ_m by 0.10									
σ=0.2	-0.52%	-0.52%	-0.51%	-0.50%	-0.49%	-0.48%	-0.47%	-0.46%	-0.45%
σ=0.3	-0.51%	-0.50%	-0.49%	-0.48%	-0.47%	-0.46%	-0.45%	-0.44%	-0.43%
σ=0.401	-0.50%	**-0.49%**	-0.48%	-0.47%	-0.46%	-0.44%	-0.43%	-0.42%	-0.41%
σ=0.5	-0.48%	-0.47%	-0.46%	-0.45%	-0.44%	-0.43%	-0.42%	-0.40%	-0.39%
σ=0.6	-0.47%	-0.46%	-0.45%	-0.44%	-0.43%	-0.41%	-0.40%	-0.39%	-0.37%
σ=0.7	-0.46%	-0.45%	-0.44%	-0.42%	-0.41%	-0.40%	-0.38%	-0.37%	-0.36%
σ=0.85	-0.44%	-0.43%	-0.41%	-0.40%	-0.39%	-0.38%	-0.36%	-0.35%	-0.33%
C. Reduce a by 0.04									
σ=0.2	0.43%	0.39%	0.35%	0.30%	0.25%	0.20%	0.14%	0.08%	0.02%
σ=0.3	0.48%	0.44%	0.39%	0.35%	0.30%	0.24%	0.18%	0.13%	0.07%
σ=0.401	0.52%	**0.48%**	0.44%	0.39%	0.34%	0.29%	0.23%	0.17%	0.11%
σ=0.5	0.56%	0.52%	0.48%	0.43%	0.38%	0.33%	0.27%	0.22%	0.15%
σ=0.6	0.60%	0.56%	0.52%	0.47%	0.42%	0.37%	0.31%	0.25%	0.19%
σ=0.7	0.63%	0.59%	0.55%	0.51%	0.46%	0.41%	0.34%	0.29%	0.23%
σ=0.85	0.68%	0.64%	0.60%	0.55%	0.50%	0.45%	0.39%	0.34%	0.28%

Table 3.3: **Sensitivity Analysis for Steady-State Responses of Skill Premium (in % Change from Initial Steady State; Benchmark Case)**

	ρ=-0.6	ρ=-0.495	ρ=-0.4	ρ=-0.3	ρ=-0.2	ρ=-0.1	ρ=0.01	ρ=0.1	ρ=0.2
A. Reduce τ_c by 0.10									
σ=0.2	-0.16%	-0.15%	-0.14%	-0.13%	-0.12%	-0.10%	-0.08%	-0.06%	-0.04%
σ=0.3	-0.21%	-0.20%	-0.19%	-0.18%	-0.16%	-0.15%	-0.13%	-0.11%	-0.08%
σ=0.401	-0.26%	**-0.25%**	-0.24%	-0.23%	-0.21%	-0.20%	-0.18%	-0.16%	-0.14%
σ=0.5	-0.31%	-0.30%	-0.29%	-0.28%	-0.27%	-0.25%	-0.24%	-0.22%	-0.20%
σ=0.6	-0.36%	-0.36%	-0.35%	-0.34%	-0.33%	-0.32%	-0.30%	-0.28%	-0.26%
σ=0.7	-0.43%	-0.42%	-0.41%	-0.40%	-0.40%	-0.38%	-0.37%	-0.36%	-0.34%
σ=0.85	-0.53%	-0.53%	-0.52%	-0.52%	-0.51%	-0.50%	-0.49%	-0.48%	-0.47%
B. Reduce τ_m by 0.10									
σ=0.2	0.38%	0.36%	0.34%	0.31%	0.27%	0.24%	0.19%	0.14%	0.09%
σ=0.3	0.49%	0.46%	0.44%	0.41%	0.38%	0.35%	0.30%	0.26%	0.20%
σ=0.401	0.60%	**0.58%**	0.56%	0.53%	0.50%	0.47%	0.43%	0.38%	0.33%
σ=0.5	0.72%	0.70%	0.68%	0.66%	0.63%	0.60%	0.56%	0.52%	0.47%
σ=0.6	0.86%	0.84%	0.82%	0.80%	0.77%	0.75%	0.71%	0.67%	0.63%
σ=0.7	1.00%	0.99%	0.97%	0.95%	0.93%	0.91%	0.88%	0.84%	0.80%
σ=0.85	1.25%	1.24%	1.23%	1.22%	1.20%	1.19%	1.17%	1.14%	1.12%
C. Reduce a by 0.04									
σ=0.2	-3.46%	-3.41%	-3.36%	-3.30%	-3.23%	-3.16%	-3.06%	-2.97%	-2.85%
σ=0.3	-3.24%	-3.20%	-3.16%	-3.10%	-3.05%	-2.98%	-2.89%	-2.81%	-2.70%
σ=0.401	-3.01%	**-2.97%**	-2.93%	-2.89%	-2.84%	-2.78%	-2.71%	-2.63%	-2.54%
σ=0.5	-2.76%	-2.73%	-2.70%	-2.66%	-2.62%	-2.57%	-2.50%	-2.44%	-2.36%
σ=0.6	-2.49%	-2.46%	-2.43%	-2.40%	-2.37%	-2.33%	-2.27%	-2.22%	-2.16%
σ=0.7	-2.18%	-2.16%	-2.14%	-2.12%	-2.09%	-2.06%	-2.02%	-1.98%	-1.93%
σ=0.85	-1.67%	-1.66%	-1.65%	-1.64%	-1.62%	-1.60%	-1.58%	-1.56%	-1.53%

Table 3.4: **Sensitivity Analysis for Steady-State Responses (in % Change from Initial Steady State; Benchmark Case)**

	K	**p**	**Z**	**m**	**Ns**	**Ws/Wu**	**Cud**	**Cum**	**Csd**	**Csm**
Benchmark: $\phi = 0.8$, $\theta = 0.7$, $\kappa = 1.4$										
Reduce τ_c by 0.10	-0.59%	1.99%	-2.54%	-2.56%	-0.07%	-0.25%	-0.53%	6.23%	-0.75%	6.00%
Reduce τ_m by 0.10	1.41%	4.93%	-3.35%	6.28%	0.17%	0.58%	1.26%	-3.49%	1.78%	-2.99%
Reduce a by 0.04	1.16%	2.99%	63.70%	-2.49%	3.21%	-2.97%	0.02%	-2.89%	-4.05%	-6.84%
A. Variations in consumption openness: $\phi = 0.6$										
Reduce τ_c by 0.10	-0.86%	2.86%	-3.62%	-3.65%	-0.11%	-0.36%	-0.76%	5.09%	-1.08%	4.75%
Reduce τ_m by 0.10	1.68%	4.05%	-2.28%	7.46%	0.21%	0.69%	1.49%	-2.46%	2.12%	-1.86%
Reduce a by 0.04	1.45%	2.05%	65.70%	-1.30%	3.30%	-2.92%	0.27%	-1.74%	-3.77%	-5.70%
B. Variations in fraction of unskilled labor: $\theta = 0.9$										
Reduce τ_c by 0.10	-0.55%	2.16%	-2.66%	-2.69%	-0.06%	-0.21%	-0.53%	6.06%	-0.72%	5.86%
Reduce τ_m by 0.10	1.24%	4.78%	-3.38%	6.27%	0.13%	0.48%	1.18%	-3.44%	1.61%	-3.02%
Reduce a by 0.04	1.08%	2.21%	64.83%	-1.83%	2.68%	-2.35%	0.02%	-2.14%	-3.33%	-5.42%
C. Variations in export elasticity to relative price: $\kappa = 0.8, 3$										
Reduce τ_c by 0.10										
$\kappa = 0.8$	-0.88%	3.11%	-3.87%	-3.93%	-0.10%	-0.35%	-0.81%	4.78%	-1.13%	4.45%
$\kappa = 3$	-0.32%	1.02%	-1.33%	-1.33%	-0.04%	-0.14%	-0.28%	7.53%	-0.40%	7.39%
Reduce τ_m by 0.10										
$\kappa = 0.8$	0.59%	7.66%	-6.56%	2.73%	0.07%	0.24%	0.55%	-6.60%	0.76%	-6.41%
$\kappa = 3$	2.21%	2.53%	-0.31%	9.59%	0.30%	0.93%	1.92%	-0.60%	2.77%	0.23%
Reduce a by 0.04										
$\kappa = 0.8$	0.67%	4.59%	60.42%	-4.43%	2.87%	-2.80%	-0.39%	-4.76%	-4.20%	-8.41%
$\kappa = 3$	1.64%	1.55%	66.82%	-0.66%	3.56%	-3.14%	0.40%	-1.13%	-3.90%	-5.36%

Table 3.5: **MS Case Calibration and Equilibrium**

A. The Economy	
Preference parameters:	$\gamma = -1.5$, $\eta = 1.75$, $\phi = 0.8$, $\beta = 0.05$
Production parameters:	$\sigma = 0.401$, $\rho = -0.495$, $\alpha = 0.444$, $\omega_1 = 0.626$, $\omega_2 = 0.265$
Depreciation rate:	$\delta = 0.06$
World interest rate:	$i^* = 0.035$
Premium on borrowing:	$a = 0.1$
Weight on the premium:	$\xi = 1$
Tariffs:	$\tau_c = 0.22$, $\tau_m = 0.11$
Fraction of unskilled workers:	$\theta = 0.7$
Export parameters:	$\kappa = 1.4$, $X^* = 1.875$
B.Key Equilibirum Quantities	
Capital to GDP ratio:	3.000
Debt to GDP ratio:	0.447
Tariff revenues to GDP ratio:	0.048
Aggregate labor share of income:	0.650
Skilled labor share of income:	0.200
Unskilled labor share of income:	0.450
Skill premium:	1.458
Imported materials to GDP ratio:	0.182
Trade balance to GDP ratio	0.022

Table 3.6: **Key On-Impact Responses to Tariffs Reduction and Financial Liberalization (MS Case)**

A. Aggregate quantities

	GDP	$\dot{K}$	**K/GDP**	**p**	$\dot{Z}$	**pZ/GDP**	**m**	**EXP/GDP**	**TB/GDP**
Initial Eq $\tau_c = 0.22$, $\tau_m = 0.11$, $a = 0.1$	0.3166	0.0000	3.0000	0.1276	0.0000	0.4467	0.4511	0.3316	0.0223
Reduce τ_c by 0.10	0.3146	-0.0018	3.0190	0.1316	-0.0056	0.4635	0.4390	0.3484	0.0257
% change	(-0.63%)		(0.63%)	(3.12%)		(3.77%)	(-2.67%)	(5.05%)	(15.22%)
Reduce τ_m by 0.10	0.3151	0.0028	3.0139	0.1321	0.0058	0.4645	0.4762	0.3497	0.0210
% change	(-0.46%)		(0.46%)	(3.51%)		(4.00%)	(5.56%)	(5.44%)	(-5.76%)
Reduce a by 0.04	0.3193	0.0069	2.9743	0.1219	0.0388	0.4232	0.4670	0.3086	0.0036
% change	(0.86%)		(-0.86%)	(-4.44%)		(-5.25%)	(3.54%)	(-6.96%)	(-83.70%)

B. Impact on labor

	Nu	**Ns**	**Wu**	**Ws**	**Ws/Wu**	**Cud**	**Cum**	**Csd**	**Csm**
Initial Eq $\tau_c = 0.22$, $\tau_m = 0.11$, $a = 0.1$	0.3636	0.2586	0.5596	0.8161	1.4583	0.1628	0.2615	0.2766	0.4442
Reduce τ_c by 0.10	0.3636	0.2584	0.5580	0.8092	1.4502	0.1623	0.2754	0.2744	0.4654
% change	(0.00%)	(-0.09%)	(-0.29%)	(-0.84%)	(-0.56%)	(-0.29%)	(5.33%)	(-0.81%)	(4.77%)
Reduce τ_m by 0.10	0.3636	0.2602	0.5631	0.8256	1.4662	0.1638	0.2541	0.2792	0.4332
% change	(0.00%)	(0.63%)	(0.62%)	(1.17%)	(0.55%)	(0.62%)	(-2.80%)	(0.94%)	(-2.48%)
Reduce a by 0.04	0.3636	0.2575	0.5615	0.8290	1.4763	0.1634	0.2730	0.2812	0.4678
% change	(0.00%)	(-0.43%)	(0.34%)	(1.58%)	(1.24%)	(0.34%)	(4.40%)	(1.67%)	(5.31%)

Table 3.7: **Key Steady-State Responses to Tariffs Reduction and Financial Liberalization (MS Case)**

A. Aggregate quantities

	GDP	**K**	**K/GDP**	**p**	**Z**	**pZ/GDP**	**m**	**EXP/GDP**	**TB/GDP**
Initial Eq $\tau_c = 0.22$, $\tau_m = 0.11$, $a = 0.1$	0.3166	0.9497	3.0000	0.1276	1.1082	0.4467	0.4511	0.3316	0.0223
Reduce τ_c by 0.10	0.3142	0.9410	2.9950	0.1303	1.0755	0.4459	0.4408	0.3440	0.0223
% change	(-0.75%)	(-0.91%)	(-0.17%)	(2.09%)	(-2.95%)	(-0.17%)	(-2.28%)	(3.72%)	(-0.17%)
Reduce τ_m by 0.10	0.3164	0.9702	3.0661	0.1335	1.0821	0.4565	0.4763	0.3535	0.0228
% change	(-0.04%)	(2.17%)	(2.20%)	(4.63%)	(-2.35%)	(2.20%)	(5.58%)	(6.58%)	(2.20%)
Reduce a by 0.04	0.3170	0.9545	3.0109	0.1318	1.7966	0.7471	0.4436	0.3467	0.0374
% change	(0.15%)	(0.51%)	(0.36%)	(3.33%)	(62.12%)	(67.27%)	(-1.67%)	(4.54%)	(67.27%)

B. Impact on labor

	Nu	**Ns**	**Wu**	**Ws**	**Ws/Wu**	**Cud**	**Cum**	**Csd**	**Csm**
Initial Eq $\tau_c = 0.22$, $\tau_m = 0.11$, $a = 0.1$	0.3636	0.2586	0.5596	0.8161	1.4583	0.1628	0.2615	0.2766	0.4442
Reduce τ_c by 0.10	0.3636	0.2583	0.5574	0.8064	1.4467	0.1621	0.2779	0.2734	0.4685
% change	(0.00%)	(-0.11%)	(-0.40%)	(-1.19%)	(-0.79%)	(-0.40%)	(6.27%)	(-1.15%)	(5.47%)
Reduce τ_m by 0.10	0.3636	0.2593	0.5649	0.8393	1.4858	0.1643	0.2523	0.2842	0.4363
% change	(0.00%)	(0.27%)	(0.94%)	(2.84%)	(1.88%)	(0.94%)	(-3.52%)	(2.75%)	(-1.80%)
Reduce a by 0.04	0.3636	0.2667	0.5609	0.7853	1.4000	0.1632	0.2536	0.2632	0.4091
% change	(0.00%)	(3.14%)	(0.22%)	(-3.78%)	(-3.99%)	(0.22%)	(-3.01%)	(-4.83%)	(-7.90%)

C. Intertemporal welfare effects (in terms of equivalent percentage change in consumption)

	Unskilled	**Skilled**
Reduce τ_c by 0.10	0.88%	0.19%
Reduce τ_m by 0.10	-0.08%	0.68%
Reduce a by 0.04	0.59%	0.29%

Table 3.8: **Creditor Case Calibration and Equilibrium**

A. The Economy	
Preference parameters:	$\gamma = -1.5$, $\eta = 1.75$, $\phi = 0.8$, $\beta = 0.035$
Production parameters:	$\sigma = 0.401$, $\rho = -0.495$, $\alpha = 0.528$, $\omega = 0.851$, $\mu = 0.17$
Depreciation rate:	$\delta = 0.06$
World interest rate:	$i^{*} = 0.05$
Premium on borrowing:	$a = 0.1$
Weight on the premium:	$\xi = 1$
Tariffs:	$\tau_c = 0.22$, $\tau_m = 0.11$
Fraction of unskilled workers:	$\theta = 0.7$
Export parameters:	$\kappa = 1.4$, $X^{*} = 1.887$
B.Key Equilibrium Quantities	
Capital to GDP ratio:	3.419
Debt to GDP ratio:	-0.517
Tariff revenues to GDP ratio:	0.048
Aggregate labor share of income:	0.655
Skilled labor share of income:	0.218
Unskilled labor share of income:	0.438
Skill premium:	1.628
Imported materials to GDP ratio:	0.181
Trade balance to GDP ratio:	-0.018
Stable eigenvalues:	-0.170 -0.034

Table 3.9: **Key On-Impact Responses to Tariffs Reduction and Financial Liberalization (Creditor Case)**

A. Aggregate quantities

	GDP	$\dot{K}$	**K/GDP**	**p**	$\dot{Z}$	**pZ/GDP**	**m**	**EXP/GDP**	**TB/GDP**
Initial Eq $\tau_c = 0.22$, $\tau_m = 0.11$, $a = 0.1$	0.3426	0.0000	3.4189	0.1230	0.0000	-0.5167	0.5040	0.2928	-0.0181
Reduce τ_c by 0.10	0.3409	-0.0006	3.4369	0.1259	-0.0003	-0.5320	0.4895	0.3043	-0.0183
% change	(-0.52%)		(0.53%)	(2.42%)		(2.96%)	(-2.87%)	(3.94%)	(1.32%)
Reduce τ_m by 0.10	0.3403	0.0024	3.4423	0.1280	0.0109	-0.5417	0.5379	0.3119	-0.0227
% change	(-0.68%)		(0.68%)	(4.12%)		(4.83%)	(6.73%)	(6.54%)	(25.66%)
Reduce a by 0.04	0.3403	-0.0064	3.4429	0.1266	-0.0508	-0.5358	0.4840	0.3071	-0.0029
% change	(-0.70%)		(0.70%)	(2.96%)		(3.69%)	(-3.96%)	(4.91%)	(-83.98%)

B. Impact on labor

	Nu	**Ns**	**Wu**	**Ws**	**Ws/Wu**	**Cud**	**Cum**	**Csd**	**Csm**
Initial Eq $\tau_c = 0.22$, $\tau_m = 0.11$, $a = 0.1$	0.3636	0.2592	0.5891	0.9591	1.6282	0.1714	0.2856	0.3248	0.5413
Reduce τ_c by 0.10	0.3636	0.2588	0.5861	0.9560	1.6312	0.1705	0.3022	0.3239	0.5742
% change	(0.00%)	(-0.17%)	(-0.51%)	(-0.32%)	(0.19%)	(-0.51%)	(5.82%)	(-0.26%)	(6.08%)
Reduce τ_m by 0.10	0.3636	0.2594	0.5957	0.9691	1.6269	0.1733	0.2773	0.3281	0.5251
% change	(0.00%)	(0.07%)	(1.12%)	(1.04%)	(-0.08%)	(1.12%)	(-2.89%)	(1.02%)	(-2.99%)
Reduce a by 0.04	0.3636	0.2577	0.5849	0.9585	1.6388	0.1702	0.2744	0.3252	0.5238
% change	(0.00%)	(-0.61%)	(-0.71%)	(-0.06%)	(0.66%)	(-0.71%)	(-3.92%)	(0.14%)	(-3.22%)

Table 3.10: **Key Steady-State Responses to Tariffs Reduction and Financial Liberalization (Creditor Case)**

A. Aggregate quantities									
	GDP	**K**	**K/GDP**	**p**	**Z**	**pZ/GDP**	**m**	**EXP/GDP**	**TB/GDP**
Initial Eq $\tau_c = 0.22$, $\tau_m = 0.11$, $a = 0.1$	0.3426	1.1715	3.4189	0.1230	-1.4399	-0.5167	0.5040	0.2928	-0.0181
Reduce τ_c by 0.10	0.3402	1.1637	3.4202	0.1258	-1.3983	-0.5169	0.4892	0.3044	-0.0181
% change	(-0.70%)	(-0.66%)	(0.04%)	(2.30%)	(-2.89%)	(0.04%)	(-2.93%)	(3.96%)	(0.04%)
Reduce τ_m by 0.10	0.3410	1.1862	3.4787	0.1295	-1.3842	-0.5258	0.5328	0.3164	-0.0184
% change	(-0.49%)	(1.25%)	(1.75%)	(5.33%)	(-3.87%)	(1.75%)	(5.73%)	(8.06%)	(1.75%)
Reduce a by 0.04	0.3419	1.1625	3.4005	0.1198	-2.4439	-0.8566	0.5160	0.2830	-0.0300
% change	(-0.23%)	(-0.77%)	(-0.54%)	(-2.55%)	(69.72%)	(65.77%)	(2.39%)	(-3.33%)	(65.77%)

B. Impact on labor									
	Nu	**Ns**	**Wu**	**Ws**	**Ws/Wu**	**Cud**	**Cum**	**Csd**	**Csm**
Initial Eq $\tau_c = 0.22$, $\tau_m = 0.11$, $a = 0.1$	0.3636	0.2592	0.5891	0.9591	1.6282	0.1714	0.2856	0.3248	0.5413
Reduce τ_c by 0.10	0.3636	0.2590	0.5855	0.9508	1.6239	0.1703	0.3023	0.3221	0.5715
% change	(0.00%)	(-0.08%)	(-0.61%)	(-0.87%)	(-0.26%)	(-0.61%)	(5.84%)	(-0.84%)	(5.59%)
Reduce τ_m by 0.10	0.3636	0.2596	0.5958	0.9749	1.6362	0.1733	0.2742	0.3299	0.5220
% change	(0.00%)	(0.15%)	(1.14%)	(1.64%)	(0.49%)	(1.14%)	(-3.97%)	(1.59%)	(-3.55%)
Reduce a by 0.04	0.3636	0.2535	0.5895	0.9807	1.6636	0.1715	0.2933	0.3347	0.5724
% change	(0.00%)	(-2.23%)	(0.08%)	(2.25%)	(2.17%)	(0.08%)	(2.70%)	(3.05%)	(5.75%)

C. Intertemporal welfare effects (in terms of equivalent percentage change in consumption)		
	Unskilled	**Skilled**
Reduce τ_c by 0.10	0.70%	0.76%
Reduce τ_m by 0.10	0.13%	0.37%
Reduce a by 0.04	-0.24%	1.72%

Figures

Figure 3.1: **Dynamics of the Skill Premium, Capital-Skill Complementarity (CSC) Component and Relative Quantity (RQ) Component**

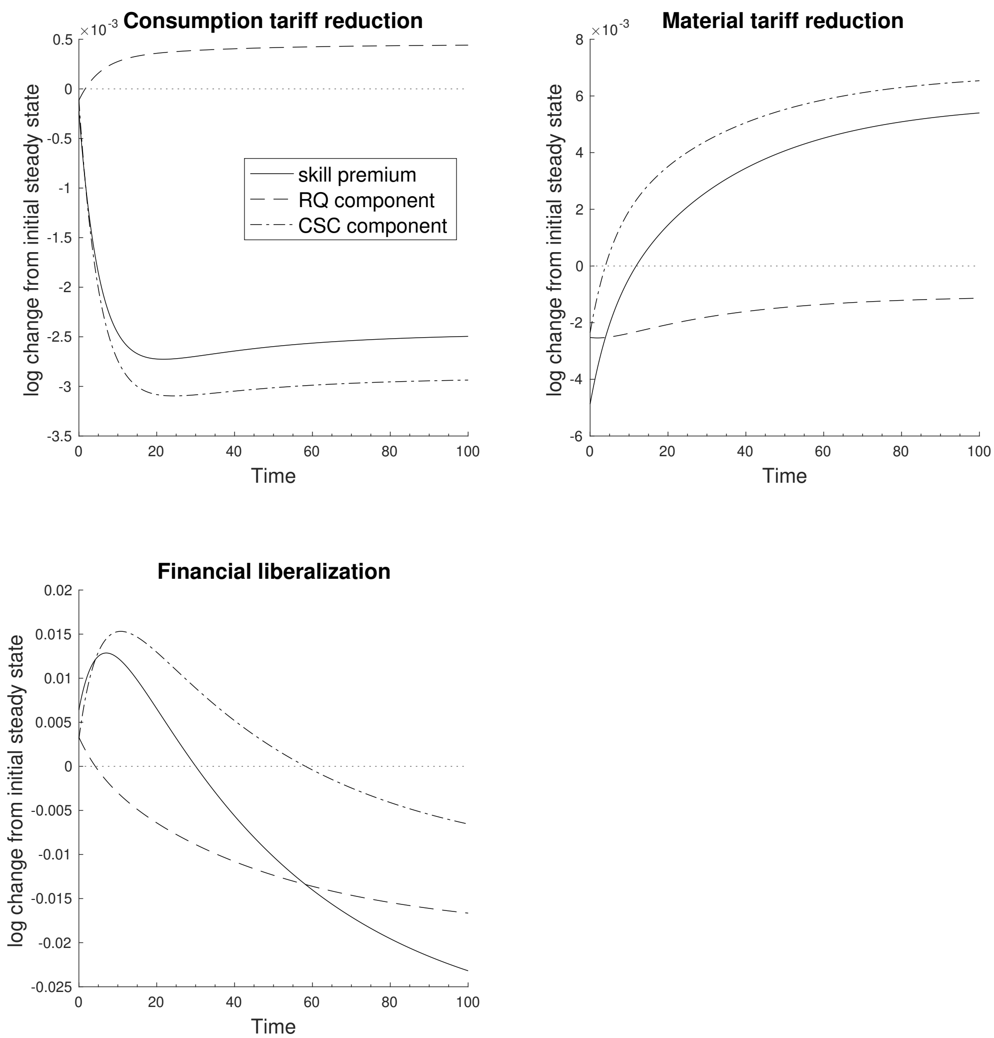


Figure 3.2: **Dynamics of Tariffs Reduction and Financial Liberalization for the Creditor Economy**

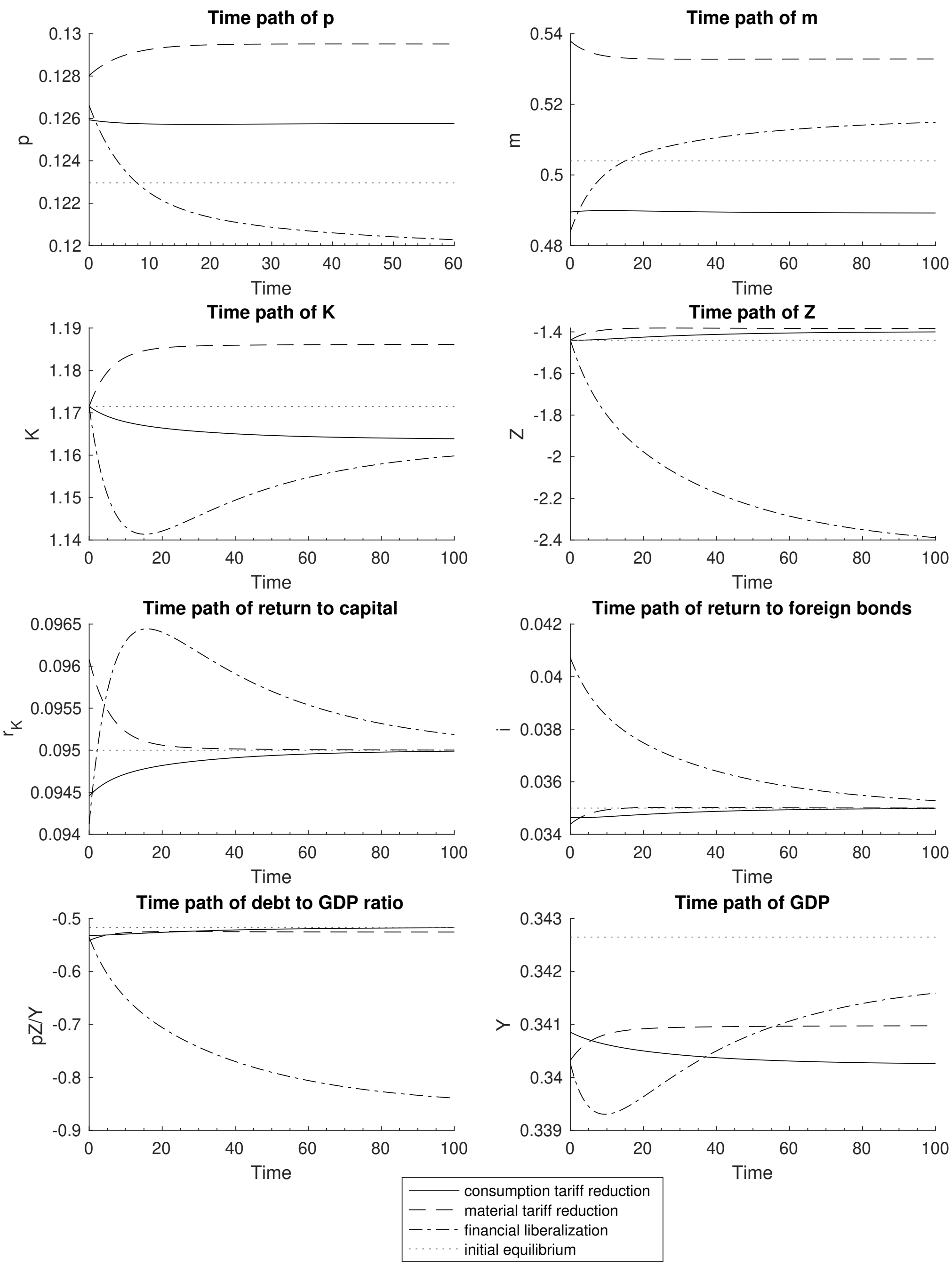
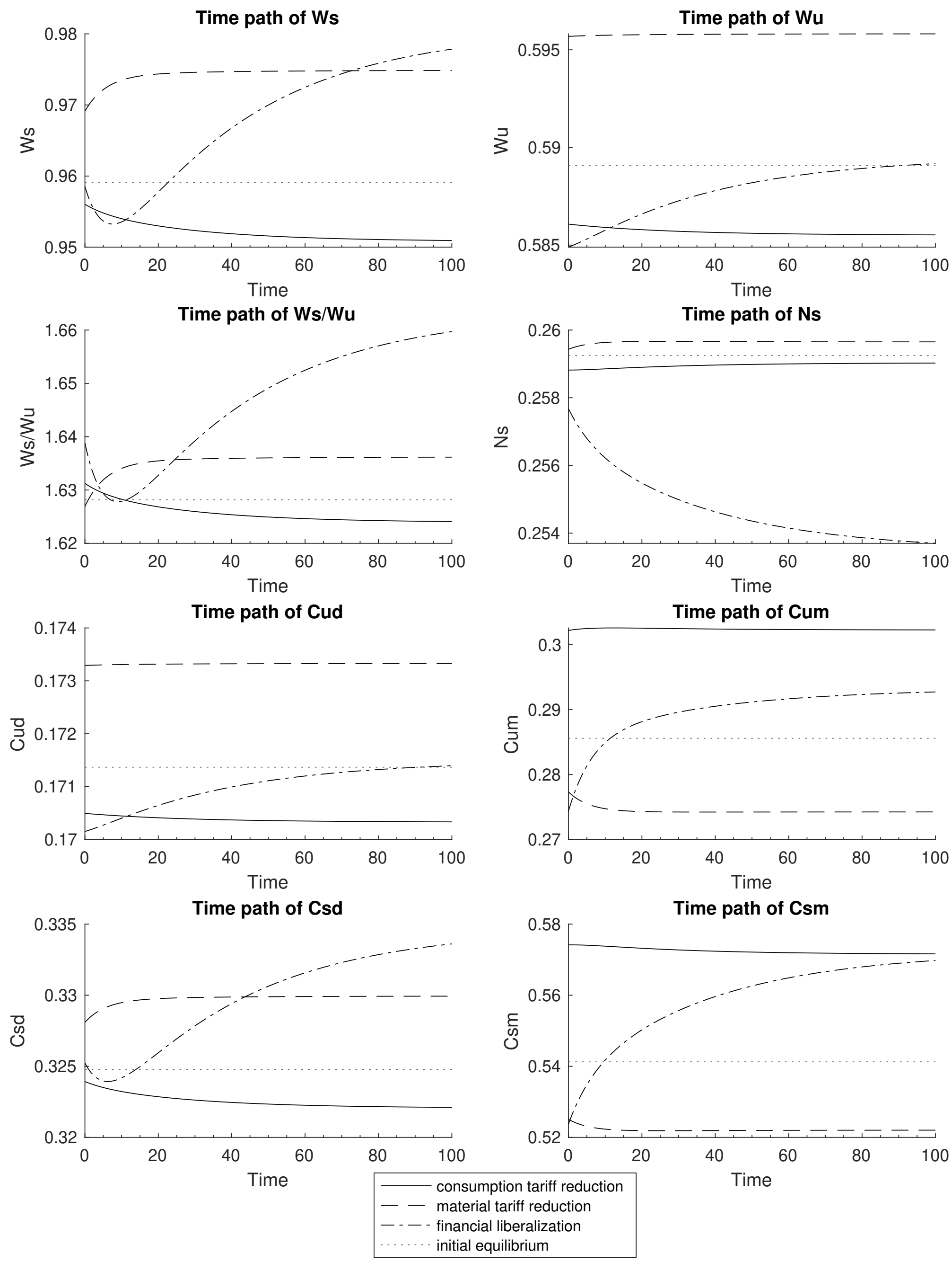


Figure 3.3: **Dynamics of Tariffs Reduction and Financial Liberalization for the Creditor Economy (Continued)**



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Appendix A

MARKET POWER AND LABOR MARKET TRENDS

A.1 Measurement of Markups

I follow the methodology used in Barkai (2016) to measure markups.[1] In particular, equation (1.6) implies the markup levels are directly tied with the profit share[2], I thus compute the series of profit share and then use it to back out the series of markups. To construct profit share, the key is to distinguish profit from cost of capital in the total capital income which is equal to the gross value added minus the labor income, both of which can be directly obtained from Bureau of Economic Analysis (BEA)'s National Income and Product Account (NIPA). Following Hall and Jorgenson (1967), also consistent with the model, the cost of capital is equal to the product of the required rate of return on capital and the value of the capital stock, where the required rate of return r is determined by equation (1.14). To express r in terms of the variables which can be directly obtained from the data, I do the following transformation of equation (1.14)[3]:

$$r_{t+1} = \frac{1}{q_t}\left(\frac{C_{t+1}}{C_t\beta} - \frac{1-\delta_{t+1}}{\frac{q_{t+1}}{q_t}}\right) \tag{A.1}$$

$$\frac{P_t}{P_{t+1}} P_{t+1} r_{t+1} = P_t \frac{1}{q_t}\left(1 + \tilde{r}_{t+1} - (1-\delta_{t+1})\frac{\frac{P_{t+1}}{q_{t+1}}}{\frac{P_t}{q_t}}\frac{P_t}{P_{t+1}}\right) \tag{A.2}$$

$$(1+\pi_{t+1})^{-1} P_{t+1} r_{t+1} = \xi_t\left(1 + \tilde{r}_{t+1} - (1-\delta_{t+1})\frac{\xi_{t+1}}{\xi_t}(1+\pi_{t+1})^{-1}\right) \tag{A.3}$$

[1] See Basu (2019) for a discussion of the issues with different methodologies used in the literature to measure markups.

[2] Equation(1.6) hinges on the assumption that the production exhibits constant return to scale.

[3] I add time subscript to the depreciation rate δ here to explicitly allow for time variation.

$$(1+\pi_{t+1})^{-1}P_{t+1}r_{t+1} = \xi_t(1+\tilde{r}_{t+1} - (1-\delta_{t+1})(1+\pi_{K,t+1})(1+\pi_{t+1})^{-1}) \tag{A.4}$$

$$(1+\pi_{t+1})^{-1}\frac{P_{t+1}r_{t+1}}{\xi_{t+1}} = \frac{\xi_t}{\xi_{t+1}}(1+\tilde{r}_{t+1} - (1-\delta_{t+1})(1+\pi_{K,t+1})(1+\pi_{t+1})^{-1}) \tag{A.5}$$

$$(1+\pi_{t+1})^{-1}\tilde{R}_{t+1} = (1+\pi_{K,t+1})^{-1}(1+\tilde{r}_{t+1} - (1-\delta_{t+1})(1+\pi_{K,t+1})(1+\pi_{t+1})^{-1}) \tag{A.6}$$

$$\tilde{R}_{t+1} \approx \tilde{r}_{t+1} + \delta_{t+1} - \pi_{K,t+1} + \pi_{t+1} \tag{A.7}$$

$$\tilde{R}_{t+1} \approx i^D_{t+1} + \delta_{t+1} - \pi_{K,t+1} \tag{A.8}$$

$$\tilde{R}_{t+1} \approx i^D_{t+1} + \delta_{t+1} - E_t[\pi_{K,t+1}] \tag{A.9}$$

where equation (A.9) is the stochastic version of equation (A.8). r_{t+1} is the required rate of return of capital in units of consumption goods per efficiency unit of investment goods (capital), $\frac{1}{q_t}$ is the relative price of investment goods in units of consumption goods per efficiency unit of investment goods, $1+\tilde{r}_{t+1} \equiv \frac{C_{t+1}}{C_t\beta}$ is the gross real interest rate of a riskless bond denominated in units of consumption goods, P_t is the nominal price of consumption goods, $\pi_{t+1} \equiv \frac{P_{t+1}}{P_t} - 1$ is the inflation rate of consumption goods, $\xi_t \equiv \frac{P_t}{q_t}$ is the nominal price of investment goods in units of dollars per efficiency unit of investment goods, $\pi_{K,t+1} \equiv \frac{\xi_{t+1}}{\xi_t} - 1$ is the inflation rate of investment goods, $\tilde{R}_{t+1} \equiv \frac{P_{t+1}r_{t+1}}{\xi_{t+1}}$ is the nominal required rate of return of capital in units of dollars per dollar of capital, i^D_{t+1} is the net nominal interest rate of a riskless bond denominated in dollars, which measures the debt cost of capital.

To account for both debt and equity financing, following Barkai (2016), I rewrite equation (A.9) as:

$$\tilde{R}_{t+1} \approx (\frac{D_t}{D_t+E_t}i^D_{t+1} + \frac{E_t}{D_t+E_t}i^E_{t+1}) + \delta_{t+1} - E_t[\pi_{K,t+1}] \tag{A.10}$$

where D_t is the market value of debt, E_t is the market value of equity, i^E_{t+1} is the equity cost of capital.

Most of the variables on the right-hand side of equation (A.10) can be either directly obtained or easily constructed from the data. The market value of debt and equity are obtained from Integrated Macroeconomic Accounts for the United States.[4] I use Moody's Aaa corporate bond yield, which is available through FRED, to measure the debt cost of capital. Equity cost of capital is not directly observed in the data. I follow Barkai (2016)'s main specification to construct equity cost of capital as the sum of the debt cost of capitals and a 5% equity risk premium. Data on the depreciation rate and inflation rate of capital are taken from BEA's Fixed Asset Table (FAT). Depreciation rate equals the ratio of current-cost depreciation to the sum of current-cost depreciation and current-cost net stock of capital. To construct the inflation rate of capital, I first construct the implicit price deflator of capital as the ratio of the current-cost net stock of capital to the chain-type quantity index for net stock of capital. Realized inflation rate of capital equals the growth rate of the implicit price deflator. I then construct the expected inflation rate of capital as the 3-year moving average of the realized inflation rate of capital. Plugging in the variables constructed above into equation (A.10), this gives me a series of the required rate of return of capital, $\tilde{R}$.

Denote the nominal value of capital stock as $\tilde{K}_t \equiv \xi_t K_t$. Then capital share can be expressed as:

$$CS_t \equiv \frac{r_t K_t}{Y_t} = \frac{P_t r_t K_t}{P_t Y_t} = \frac{(\frac{P_t r_t}{\xi_t})(\xi_t K_t)}{P_t Y_t} = \frac{\tilde{R}_t \tilde{K}_t}{P_t Y_t}$$

where $\tilde{R}_t \tilde{K}_t$ is the nominal value of the capital cost and $P_t Y_t$ is the nominal value of gross value added. For the corporate sector, data on $\tilde{K}_t$ is taken from the FAT Table 4.1 (line 17) as current-cost net stock of capital, and data on $P_t Y_t$ is taken from the NIPA Table 1.14 (line 1) as gross value added in current dollars.

In NIPA Table 1.14, gross value added (line 1) equals the sum of compensation of employees (line 4), gross operating surplus (line 2 + line 8) and taxes on production and imports less subsidies (line 7). Decomposing gross operating surplus into capital cost and profit, I get the expression for the profit share:

$$PS_t = 1 - LS_t - CS_t - TS_t$$

[4] I construct the market value of debt as the sum of debt securities and loans and the market value of equity as the corporate equity of the non-financial corporate sector.

where LS_t is the labor share, i.e. the ratio of compensation of employees to gross value added, TS_t is the tax share, i.e. the ratio of taxes on production and imports less subsidies to gross value added.[5] Given also the capital share, CS_t, constructed earlier, I obtain a series of profit share, PS_t.

Lastly, equation (1.6) implies

$$\mu_t = \frac{1}{1 - PS_t}$$

which allows me to construct the series of markups, μ_t, from the series of profit share.

A.2 Additional Qualitative Results

The following propositions summarize the qualitative effect of investment-specific technology on wage polarization, wage growth and labor share.

Proposition A.2.1 *The following comparative static results hold:*

1. $\frac{\partial r}{\partial q} < 0$. *An increase in steady state q decreases the rental rate of capital.*

2. $\frac{\partial K}{\partial q} > 0$. *An increase in steady state q increases capital stock.*

3. $\frac{\partial W_n}{\partial q} > 0$ *and* $\frac{\partial W_r}{\partial q} > 0$. *An increase in steady state q increases both the skill price of non-routine task and routine task.*

4. $\frac{\partial \frac{W_n}{W_r}}{\partial q} > 0$. *An increase in steady state q increases the non-routine wage premium.*

5. $\frac{\partial \bar{\tau}}{\partial q} > 0$. *An increase in steady state q increases (decreases) the employment of workers in non-routine task (routine task).*

Proof. See Appendix A.3. ■

The investment-specific technology growth drives the changes of the model's endogenous variables by reducing the rental rate of capital. As the price of capital becomes lower, firms tend to demand more capital, leading to more capital stock in steady state.

---

[5] Taxes on production and imports do not include taxes on income, and thus it is unclear how to attribute it to factors of production and profits. See Chapter2 of the NIPA handbook for the definition of taxes on production and imports: `https://www.bea.gov/sites/default/files/methodologies/nipa-handbook-all-chapters.pdf`.

As capital being favored more by the firm due to the reduced rental price, it tends to increase the capital-labor ratio and thus the marginal product of labor in both routine and non-routine tasks, raising the skill prices. Through the capital-task complementarity effect, the increase in capital increases the non-routine wage premium. The increase in the non-routine wage premium further induces more workers to be employed in the non-routine task and less in the routine task.

The effect of investment-specific technology on the labor share is shown by the following proposition.

Proposition A.2.2 *The following comparative static results hold:*

1. $\frac{\partial LS}{\partial q} < 0$ *and* $\frac{\partial RLS}{\partial q} < 0$ *if* $\gamma_n \geq 1$*. An increase in steady state* q *decreases aggregate labor share share and routine labor share if* $\gamma_n \geq 1$*.*

2. $\frac{\partial LS}{\partial q} > 0$, $\frac{\partial RLS}{\partial q} \geq 0$ *(equal to* 0 *only if* $\gamma_r = 1$*) and* $\frac{\partial NLS}{\partial q} > 0$ *if* $\gamma_r \leq 1$*. An increase in steady state* q *(weakly) increases aggregate labor share, routine labor share and non-routine labor share if* $\gamma_r \leq 1$*.*

3. $\frac{\partial RLS}{\partial q} < 0$ *and* $\frac{\partial NLS}{\partial q} > 0$ *if* $\gamma_n < 1 < \gamma_r$*. An increase in steady state* q *decreases routine labor share and increases non-routine labor share if* $\gamma_n < 1 < \gamma_r$*.*

Proof. See Appendix A.3. ■

When $1 \leq \gamma_n < \gamma_r$, both routine labor and non-routine labor are gross substitutes with capital. Then a decrease in the rental rate of capital implied by the investment-specific technology growth leads to a decrease in aggregate labor share. On the other hand, if $\gamma_n < \gamma_r \leq 1$, both routine labor and non-routine labor are gross complements with capital, implying that a decrease in the rental rate of capital leads to an increase in aggregate labor share. Under the condition that $\gamma_n < 1 < \gamma_r$ it indicates the investment-specific technology growth will drive up the non-routine labor share and reduce the routine labor share, which is consistent with the observed long-term trends of labor share by the two groups of occupations. However, the partial effect of q on the aggregate labor share can't be unambiguously signed in this case.

The effect of q on labor income relative to business cost is qualitatively the same with that on labor share shown in Proposition A.2.2, because μ is held constant, which implies the profit share is constant, when calculating the partial effect of q. Thus q affects the labor share only through affecting the labor income relative to business cost. By comparing these results with Proposition 1.5.2, it is easy to see that an increase in markups has the exact opposite effect on labor income relative to business cost to an increase in investment-specific technology. However, on top of affecting labor income relative to business cost, an increase in markups also increases the profit share, which tends to reduce the labor share.

A.3 Proofs

A.3.1 Proof of Proposition 1.5.1

Dividing equation (1.24) by equation (1.25), I get the following expression for $\frac{W_n}{W_r}$:

$$\frac{W_n}{W_r} = \frac{\Phi_1(1-\Phi_2)}{1-\Phi_1}(\Phi_2(\frac{K}{L_n})^\rho + (1-\Phi_2))^{\frac{\sigma-\rho}{\rho}}(\frac{L_r}{L_n})^{1-\sigma} \tag{A.11}$$

Combining equation (A.11) with equations (1.18), (1.22) and (1.23), it gives:

$$\xi(\bar{\tau}^{\frac{1}{2}}) = \frac{\Phi_1(1-\Phi_2)}{1-\Phi_1}(\Phi_2(\frac{K}{2\bar{\tau}^{\frac{1}{2}}})^\rho + (1-\Phi_2))^{\frac{\sigma-\rho}{\rho}}(\frac{(1-\bar{\tau})\xi}{2\bar{\tau}^{\frac{1}{2}}})^{1-\sigma} \tag{A.12}$$

This equation relates $\bar{\tau}$ with K. Taking total derivative with respect to $\bar{\tau}$ and K of it, I obtain:

$$[\frac{(1-\bar{\tau})+(1-\sigma)(1+\bar{\tau})}{2\bar{\tau}(1-\bar{\tau})} + \frac{(\sigma-\rho)\Phi_2(\frac{K}{2\bar{\tau}^{\frac{1}{2}}})^{\rho-1}\frac{\bar{\tau}^{-\frac{1}{2}}K}{4\bar{\tau}}}{\Phi_2(\frac{K}{2\bar{\tau}^{\frac{1}{2}}})^\rho + (1-\Phi_2)}]d\tau$$
$$= (\sigma-\rho)\frac{\Phi_2(\frac{K}{2\bar{\tau}^{\frac{1}{2}}})^{\rho-1}\frac{1}{2\bar{\tau}^{\frac{1}{2}}}}{\Phi_2(\frac{K}{2\bar{\tau}^{\frac{1}{2}}})^\rho + (1-\Phi_2)}dK$$

Under the assumption of capital non-routine task complementarity, i.e. $\sigma > \rho$, it is easy to see that $\frac{dK}{d\bar{\tau}} > 0$.

Equation (A.12) can be also written as:

$$\xi(\bar{\tau}^{\frac{1}{2}}) = \frac{\Phi_1(1-\Phi_2)}{1-\Phi_1}(\Phi_2(\frac{K}{L_n})^{\rho} + (1-\Phi_2))^{\frac{\sigma-\rho}{\rho}}(\frac{(1-\bar{\tau})\xi}{2\bar{\tau}^{\frac{1}{2}}})^{1-\sigma} \tag{A.13}$$

Taking total derivative with respect to $\bar{\tau}$ and $\frac{K}{L_n}$ of equation (A.13), it gives:

$$\frac{(1-\bar{\tau}) + (1-\sigma)(1+\bar{\tau})}{2\bar{\tau}(1-\bar{\tau})} d\bar{\tau} = (\sigma - \rho)\frac{\Phi_2(\frac{K}{2\bar{\tau}^{\frac{1}{2}}})^{\rho-1}}{\Phi_2(\frac{K}{2\bar{\tau}^{\frac{1}{2}}})^{\rho} + (1-\Phi_2)} d(\frac{K}{L_n}) \tag{A.14}$$

which implies $\frac{d\frac{K}{L_n}}{d\bar{\tau}} > 0$.

Equation (1.23) directly implies $\frac{dL_r}{d\bar{\tau}} < 0$. $\frac{dK}{d\bar{\tau}} > 0$ and $\frac{dL_r}{d\bar{\tau}} < 0$ lead to $\frac{d(\frac{K}{L_r})}{d\bar{\tau}} > 0$.

Combining equations (1.26) and (1.27), I obtain:

$$r\mu = \Phi_1\Phi_2[\Phi_1(\Phi_2 + (1-\Phi_2)(\frac{L_n}{K})^{\rho})^{\frac{\sigma}{\rho}} + (1-\Phi_1)(\frac{L_r}{K})^{\sigma}]^{\frac{1-\sigma}{\sigma}}(\Phi_2 + (1-\Phi_2)(\frac{L_n}{K})^{\rho})^{\frac{\sigma-\rho}{\rho}} \tag{A.15}$$

Taking log on both sides and then taking total derivative of equation (A.15) with respect to r, μ, $\frac{K}{L_n}$ and $\frac{K}{L_r}$, it gives:

$$\begin{aligned}
\frac{dr}{r} + \frac{d\mu}{\mu} =& \frac{1-\sigma}{\sigma} \cdot \frac{\frac{\sigma}{\rho}\Phi_1(\Phi_2 + (1-\Phi_2)(\frac{L_n}{K})^{\rho})^{\frac{\sigma-\rho}{\rho}}(1-\Phi_2)(-\rho)(\frac{L_n}{K})^{\rho+1}}{\Phi_1(\Phi_2 + (1-\Phi_2)(\frac{L_n}{K})^{\rho})^{\frac{\sigma}{\rho}} + (1-\Phi_1)(\frac{L_r}{K})^{\sigma}} d(\frac{K}{L_n}) \\
&+ \frac{1-\sigma}{\sigma} \cdot \frac{(-\sigma)(1-\Phi_1)(\frac{L_r}{K})^{\sigma+1}}{\Phi_1(\Phi_2 + (1-\Phi_2)(\frac{L_n}{K})^{\rho})^{\frac{\sigma}{\rho}} + (1-\Phi_1)(\frac{L_r}{K})^{\sigma}} d(\frac{K}{L_r}) \\
&+ \frac{\sigma-\rho}{\rho} \cdot \frac{(1-\Phi_2)(-\rho)(\frac{L_n}{K})^{\rho+1}}{\Phi_2 + (1-\Phi_2)(\frac{L_n}{K})^{\rho}} d(\frac{K}{L_n})
\end{aligned}$$

Dividing both sides of the above equation by $d\bar{\tau}$, it gets:

$$\begin{aligned}
\frac{dr}{dq}\frac{dq}{d\bar{\tau}}\frac{1}{r} + \frac{1}{\mu}\frac{d\mu}{d\bar{\tau}} =& \frac{1-\sigma}{\sigma} \cdot \frac{\frac{\sigma}{\rho}\Phi_1(\Phi_2 + (1-\Phi_2)(\frac{L_n}{K})^{\rho})^{\frac{\sigma-\rho}{\rho}}(1-\Phi_2)(-\rho)(\frac{L_n}{K})^{\rho+1}}{\Phi_1(\Phi_2 + (1-\Phi_2)(\frac{L_n}{K})^{\rho})^{\frac{\sigma}{\rho}} + (1-\Phi_1)(\frac{L_r}{K})^{\sigma}} \cdot \frac{d(\frac{K}{L_n})}{d\bar{\tau}} \\
&+ \frac{1-\sigma}{\sigma} \cdot \frac{(-\sigma)(1-\Phi_1)(\frac{L_r}{K})^{\sigma+1}}{\Phi_1(\Phi_2 + (1-\Phi_2)(\frac{L_n}{K})^{\rho})^{\frac{\sigma}{\rho}} + (1-\Phi_1)(\frac{L_r}{K})^{\sigma}} \cdot \frac{d(\frac{K}{L_r})}{d\bar{\tau}}
\end{aligned}$$

$$+\frac{\sigma-\rho}{\rho}\cdot\frac{(1-\Phi_2)(-\rho)(\frac{L_n}{K})^{\rho+1}}{\Phi_2+(1-\Phi_2)(\frac{L_n}{K})^{\rho}}\cdot\frac{d(\frac{K}{L_n})}{d\bar{\tau}}$$

The right-hand side of the above equation is negative, as $\frac{d(\frac{K}{L_n})}{d\bar{\tau}} > 0$, $\frac{d(\frac{K}{L_r})}{d\bar{\tau}} > 0$ and the coefficients on $\frac{d(\frac{K}{L_n})}{d\bar{\tau}}$ and $\frac{d(\frac{K}{L_r})}{d\bar{\tau}}$ are all negative. Equation (1.19) directly implies $\frac{dr}{dq} < 0$. Thus, it results in $\frac{\partial\bar{\tau}}{\partial q} > 0$ and $\frac{\partial\bar{\tau}}{\partial\mu} < 0$.

$\frac{\partial\bar{\tau}}{\partial\mu} < 0$, together with $\frac{dK}{d\bar{\tau}} > 0$, $\frac{d(\frac{K}{L_n})}{d\bar{\tau}} > 0$ and $\frac{d(\frac{K}{L_r})}{d\bar{\tau}} > 0$, implies $\frac{\partial K}{\partial\mu} < 0$, $\frac{\partial(\frac{K}{L_n})}{\partial\mu} < 0$ and $\frac{\partial(\frac{K}{L_r})}{\partial\mu} < 0$ respectively. Equation (1.18) directly leads to $\frac{d(\frac{W_n}{W_r})}{d\bar{\tau}} > 0$, which further implies $\frac{\partial(\frac{W_n}{W_r})}{\partial\mu} < 0$.

Combining equation (1.25) and equation (1.27), I get the following expression for W_r:

$$W_r=\frac{1}{\mu}(1-\Phi_1)[\Phi_1(\Phi_2(\frac{K}{L_r})^{\rho}+(1-\Phi_2)(\frac{L_n}{L_r})^{\rho})^{\frac{\sigma}{\rho}}+(1-\Phi_1)]^{\frac{1-\sigma}{\sigma}} \tag{A.16}$$

It is easy to see from equations (1.22) and (1.23) that $\frac{d(\frac{L_n}{L_r})}{d\bar{\tau}} > 0$, and thus $\frac{\partial(\frac{L_n}{L_r})}{\partial\mu} < 0$. Together with $\frac{\partial(\frac{K}{L_r})}{\partial\mu} < 0$, which is proved earlier, it implies $\frac{\partial W_r}{\partial\mu} < 0$. $\frac{\partial W_r}{\partial\mu} < 0$ and $\frac{\partial(\frac{W_n}{W_r})}{\partial\mu} < 0$ further leads to $\frac{\partial W_n}{\partial\mu} < 0$. This concludes the proof of Proposition 1.5.1.

A.3.2 Proof of Proposition A.2.1

The proof in this subsection makes use of the results proved in subsection A.3.1.

$\frac{\partial\bar{\tau}}{\partial q} > 0$, together with $\frac{dK}{d\bar{\tau}} > 0$, $\frac{d(\frac{K}{L_n})}{d\bar{\tau}} > 0$, $\frac{d(\frac{K}{L_r})}{d\bar{\tau}} > 0$, $\frac{d(\frac{W_n}{W_r})}{d\bar{\tau}} > 0$ and $\frac{d(\frac{L_n}{L_r})}{d\bar{\tau}} > 0$, implies $\frac{\partial K}{\partial q} > 0$, $\frac{\partial(\frac{K}{L_n})}{\partial q} > 0$, $\frac{\partial(\frac{K}{L_r})}{\partial q} > 0$, $\frac{\partial(\frac{W_n}{W_r})}{\partial q} > 0$ and $\frac{\partial(\frac{L_n}{L_r})}{\partial q} > 0$ respectively. Taking into account of $\frac{d(\frac{K}{L_r})}{d\bar{\tau}} > 0$, $\frac{d(\frac{L_n}{L_r})}{d\bar{\tau}} > 0$ and $\frac{\partial\bar{\tau}}{\partial q} > 0$, equation (A.16) implies $\frac{\partial W_r}{\partial q} > 0$. $\frac{\partial W_r}{\partial q} > 0$ and $\frac{\partial(\frac{W_n}{W_r})}{\partial q} > 0$ further results in $\frac{\partial W_n}{\partial q} > 0$. This concludes the proof of Proposition A.2.1.

A.3.3 Proof of Proposition 1.5.2

Equation (1.29) directly implies $\frac{\partial PS}{\partial\mu} > 0$.

By definition, aggregate labor share relative to business cost, LC, can be written as:

$$
\begin{aligned}
LC &= \frac{W_nL_n + W_rL_r}{W_nL_n + W_rL_r + rK} \\
&= \frac{1}{1 + \frac{rK}{W_nL_n + W_rL_r}} \\
&= \frac{1}{1 + \frac{\frac{rK}{W_nL_n}}{1 + \frac{W_rL_r}{W_nL_n}}}
\end{aligned}
$$

which implies

$$
\frac{\partial LC}{\partial \mu} = -LC^2 \frac{\partial(\frac{\frac{rK}{W_nL_n}}{1 + \frac{W_rL_r}{W_nL_n}})}{\partial \mu} \tag{A.17}
$$

where $\frac{rK}{W_nL_n}$, based on equations (1.24) and (1.26), can be derived as:

$$
\frac{rK}{W_nL_n} = \frac{\Phi_2}{1-\Phi_2}(\frac{K}{L_n})^{\rho} \tag{A.18}
$$

Non-routine labor share relative to business cost, NLC, can be written as:

$$
\begin{aligned}
NLC &= \frac{W_nL_n}{W_nL_n + W_rL_r + rK} \\
&= \frac{1}{1 + \frac{W_rL_r}{W_nL_n} + \frac{rK}{W_nL_n}}
\end{aligned}
$$

which implies

$$
\frac{\partial NLC}{\partial \mu} = -NLC^2 \frac{\partial(\frac{W_rL_r}{W_nL_n} + \frac{rK}{W_nL_n})}{\partial \mu} \tag{A.19}
$$

Due to the constant return to scale of the production function, $W_nL_n + W_rL_r + rK = \frac{1}{\mu}Y$. Thus, routine labor share relative to business cost, RLC, can be written as:

$$
\begin{aligned}
RLC &= \frac{W_rL_r}{W_nL_n + W_rL_r + rK} \\
&= \frac{W_rL_r}{\frac{1}{\mu}Y}
\end{aligned}
$$

which, together with equations (1.25) and (1.27), implies:

$$RLC = (1-\Phi_1)[\Phi_1(\Phi_2(\frac{K}{L_r})^\rho + (1-\Phi_2)(\frac{L_n}{L_r})^\rho)^{\frac{\sigma}{\rho}} + (1-\Phi_1)]^{-1} \tag{A.20}$$

Under the case where $\gamma_n \geq 1$ (i.e. $0 \leq \rho < \sigma < 1$), equation (A.18) implies $\frac{\partial(\frac{rK}{W_nL_n})}{\partial\mu} \leq 0$ as $\frac{\partial(\frac{K}{L_n})}{\partial\mu} < 0$ holds.[6] $\frac{\partial(\frac{W_n}{W_r})}{\partial\mu} < 0$ and $\frac{\partial(\frac{L_n}{L_r})}{\partial\mu} < 0$ leads to $\frac{\partial(\frac{W_nL_n}{W_rL_r})}{\partial\mu} < 0$, which further implies $\frac{\partial(\frac{W_rL_r}{W_nL_n})}{\partial\mu} > 0$. Combining that with $\frac{\partial(\frac{rK}{W_nL_n})}{\partial\mu} \leq 0$, equation (A.17) results in $\frac{\partial LC}{\partial\mu} > 0$. As $\frac{\partial(\frac{K}{L_n})}{\partial\mu} < 0$ and $\frac{\partial(\frac{L_n}{L_r})}{\partial\mu} < 0$, equation (A.20) implies $\frac{\partial RLC}{\partial\mu} > 0$.

Under the case where $\gamma_r \leq 1$ (i.e. $\rho < \sigma \leq 0$), equation (A.20) implies $\frac{\partial RLC}{\partial\mu} \leq 0$ ((equal to 0 only if $\gamma_r = 1$)).[7] Equation (A.18) implies $\frac{\partial(\frac{rK}{W_nL_n})}{\partial\mu} > 0$. Combining that with $\frac{\partial(\frac{W_rL_r}{W_nL_n})}{\partial\mu} > 0$, equation (A.19) implies $\frac{\partial NLC}{\partial\mu} < 0$. $\frac{\partial NLC}{\partial\mu} < 0$ and $\frac{\partial RLC}{\partial\mu} \leq 0$ lead to $\frac{\partial LC}{\partial\mu} < 0$.

Under the case where $\gamma_n < 1 < \gamma_r$ (i.e. $\rho < 0 < \sigma < 1$), equation (A.20) implies $\frac{\partial RLC}{\partial\mu} > 0$. Equation (A.18) implies $\frac{\partial(\frac{rK}{W_nL_n})}{\partial\mu} > 0$. Combining that with $\frac{\partial(\frac{W_rL_r}{W_nL_n})}{\partial\mu} > 0$, equation (A.19) implies $\frac{\partial NLC}{\partial\mu} < 0$.

This concludes the proof of Proposition 1.5.2.

A.3.4 Proof of Proposition A.2.2

By definition, aggregate labor share, LS, can be written as:

$$\begin{aligned} LS &= \frac{W_nL_n + W_rL_r}{Y} \\ &= \frac{1}{\mu}\frac{W_nL_n + W_rL_r}{\frac{1}{\mu}Y} \\ &= \frac{1}{\mu}\frac{W_nL_n + W_rL_r}{W_nL_n + W_rL_r + rK} \\ &= \frac{1}{\mu}LC \end{aligned}$$

[6] when $\gamma_n = 1$ (i.e. $\rho = 0$), the production function becomes $Y = [\Phi_1(K^{\Phi_2}L_n^{(1-\Phi_2)})^\sigma + (1-\Phi_1)L_r^\sigma]^{\frac{1}{\sigma}}$.

[7] when $\gamma_r = 1$ (i.e. $\sigma = 0$), the production function becomes $Y = (\Phi_2K^\rho + (1-\Phi_2)L_n^\rho)^{\frac{\Phi_1}{\rho}}L_r^{(1-\Phi_1)}$.

which implies

$$\frac{\partial LS}{\partial q} = \frac{1}{\mu}\frac{\partial LC}{\partial q} \tag{A.21}$$

The above result uses the fact that μ is held constant when taking partial derivative with respect to q, as both μ and q are exogenous variables in the model.

Non-routine labor share, NLS, can be written as:

$$\begin{aligned} NLS &= \frac{W_n L_n}{Y} \\ &= \frac{1}{\mu}\frac{W_n L_n}{\frac{1}{\mu}Y} \\ &= \frac{1}{\mu}\frac{W_n L_n}{W_n L_n + W_r L_r + rK} \\ &= \frac{1}{\mu}NLC \end{aligned}$$

which implies

$$\frac{\partial NLS}{\partial q} = \frac{1}{\mu}\frac{\partial NLC}{\partial q} \tag{A.22}$$

Routine labor share, RLS, can be written as:

$$\begin{aligned} RLS &= \frac{W_r L_r}{Y} \\ &= \frac{1}{\mu}\frac{W_r L_r}{\frac{1}{\mu}Y} \\ &= \frac{1}{\mu}\frac{W_r L_r}{W_n L_n + W_r L_r + rK} \\ &= \frac{1}{\mu}RLC \end{aligned}$$

which implies

$$\frac{\partial RLS}{\partial q} = \frac{1}{\mu}\frac{\partial RLC}{\partial q} \tag{A.23}$$

I first derive the effects of q on labor income relative to business cost and then use equations (A.21), (A.22) and (A.23) to relate those to the effects of q on labor share.

Under the case where $\gamma_n \geq 1$ (i.e. $0 \leq \rho < \sigma < 1$), equation (A.18) implies $\frac{\partial(\frac{rK}{W_nL_n})}{\partial q} \geq 0$ as $\frac{\partial(\frac{K}{L_n})}{\partial q} > 0$ holds. $\frac{\partial(\frac{W_n}{W_r})}{\partial q} > 0$ and $\frac{\partial(\frac{L_n}{L_r})}{\partial q} > 0$ leads to $\frac{\partial(\frac{W_nL_n}{W_rL_r})}{\partial q} > 0$, which further implies $\frac{\partial(\frac{W_rL_r}{W_nL_n})}{\partial q} < 0$. Combining that with $\frac{\partial(\frac{rK}{W_nL_n})}{\partial q} \geq 0$, equation (A.17) results in $\frac{\partial LC}{\partial q} < 0$. Equation (A.21) further leads to $\frac{\partial LS}{\partial q} < 0$. As $\frac{\partial(\frac{K}{L_n})}{\partial q} > 0$ and $\frac{\partial(\frac{L_n}{L_r})}{\partial q} > 0$, equation (A.20) implies $\frac{\partial RLC}{\partial q} < 0$. Equation (A.23) further leads to $\frac{\partial RLS}{\partial q} < 0$.

Under the case where $\gamma_r \leq 1$ (i.e. $\rho < \sigma \leq 0$), equation (A.20) implies $\frac{\partial RLC}{\partial q} \geq 0$ (equal to 0 only if $\gamma_r = 1$). Equation (A.23) further leads to $\frac{\partial RLS}{\partial q} \geq 0$ (equal to 0 only if $\gamma_r = 1$). Equation (A.18) implies $\frac{\partial(\frac{rK}{W_nL_n})}{\partial q} < 0$. Combining that with $\frac{\partial(\frac{W_rL_r}{W_nL_n})}{\partial q} < 0$, equation (A.19) implies $\frac{\partial NLC}{\partial q} > 0$. $\frac{\partial NLC}{\partial q} > 0$ and $\frac{\partial RLC}{\partial q} \geq 0$ lead to $\frac{\partial LC}{\partial q} > 0$. Equation (A.21) further implies $\frac{\partial LS}{\partial q} > 0$.

Under the case where $\gamma_n < 1 < \gamma_r$ (i.e. $\rho < 0 < \sigma < 1$), equation (A.20) implies $\frac{\partial RLC}{\partial q} < 0$. Equation (A.23) further leads to $\frac{\partial RLS}{\partial q} < 0$. Equation (A.18) implies $\frac{\partial(\frac{rK}{W_nL_n})}{\partial q} < 0$. Combining that with $\frac{\partial(\frac{W_rL_r}{W_nL_n})}{\partial q} < 0$, equation (A.19) implies $\frac{\partial NLC}{\partial q} > 0$. Equation (A.22) further leads to $\frac{\partial NLS}{\partial q} > 0$.

This concludes the proof of Proposition A.2.2.

A.4 Additional Empirical Results

Table A.1: **Wage Premium, Labor Share, Skill Prices and Wage-bill Ratio on Industry Concentration**

	(1) $\Delta_5 \log(\frac{W_n}{W_r}(\%))$	(2) $\Delta_5 \log(LS)$	(3) $\Delta_5 \log(NLS)$	(4) $\Delta_5 \log(RLS)$	(5) $\Delta_5 \log(W_r)$	(6) $\Delta_5 \log(W_n)$	(7) $\Delta_5 \log(\frac{W_n L_n}{W_r L_r})$
$\Delta_5 log(CR^{50})$	0.050	-0.341***	-0.319***	-0.495***	-2.180**	-2.130**	0.178
	(0.109)	(0.103)	(0.113)	(0.173)	(0.868)	(0.854)	(0.175)
Year FE	Y	Y	Y	Y	Y	Y	Y
R^2	.017	.084	.03	.019	.0081	.0087	.0024
Observations	348	226	224	224	348	348	346

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

	(1) $\Delta_5 \log(\frac{W_n}{W_r}(\%))$	(2) $\Delta_5 \log(LS)$	(3) $\Delta_5 \log(NLS)$	(4) $\Delta_5 \log(RLS)$	(5) $\Delta_5 \log(W_r)$	(6) $\Delta_5 \log(W_n)$	(7) $\Delta_5 \log(\frac{W_n L_n}{W_r L_r})$
$\Delta_5 log(CR^{8})$	0.042	-0.200**	-0.195**	-0.357***	-1.236*	-1.194*	0.177
	(0.079)	(0.077)	(0.084)	(0.135)	(0.631)	(0.618)	(0.135)
Year FE	Y	Y	Y	Y	Y	Y	Y
R^2	.017	.068	.025	.021	.0069	.0076	.0035
Observations	347	225	223	223	347	347	345

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

	(1) $\Delta_5 \log(\frac{W_n}{W_r}(\%))$	(2) $\Delta_5 \log(LS)$	(3) $\Delta_5 \log(NLS)$	(4) $\Delta_5 \log(RLS)$	(5) $\Delta_5 \log(W_r)$	(6) $\Delta_5 \log(W_n)$	(7) $\Delta_5 \log(\frac{W_n L_n}{W_r L_r})$
$\Delta_5 log(CR^{4})$	0.050	-0.149**	-0.131	-0.315**	-0.812	-0.762	0.158
	(0.066)	(0.074)	(0.086)	(0.126)	(0.575)	(0.564)	(0.123)
Year FE	Y	Y	Y	Y	Y	Y	Y
R^2	.017	.056	.017	.021	.005	.0058	.0038
Observations	347	225	223	223	347	347	345

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table reports results of industry-level regressions of contemporaneous 5-year log-changes in non-routine wage premium, aggregate labor share, non-routine labor share, routine labor share, skill price of routine occupation, skill price of non-routine occupation and wage-bill ratio of non-routine to routine occupation on 5-year log-changes in industry concentration. The unit of observation is a Census industry. CR^{50}, CR^{8}, CR^{4} denote the share of sales by the 50, 8, and 4 largest firms within a industry respectively. Standard errors are clustered at industry level.

Appendix B

THE EFFECTS OF GLOBALIZATION ON SKILLED LABOR, UNSKILLED LABOR AND SKILL PREMIUM

B.1 Solution for the Dynamic System

As is clear from (2.13a) – (2.13d) the equilibrium dynamics are driven by the variables $x \equiv (K, Z, \lambda_S, p)$, which we can write in matrix form $\dot{x} = M(x)$. In order to analyze the local dynamics we linearize the dynamic system around its steady state (2.14a-2.14n)

$$\dot{x} = \frac{\partial M(x)}{\partial x}|_{x=\tilde{x}}(x - \tilde{x})$$

which can be expressed more explicitly in the form

$$\begin{pmatrix} \dot{K} \\ \dot{Z} \\ \dot{\lambda}_S \\ \dot{p} \end{pmatrix} = \begin{pmatrix} m_{11} & m_{12} & m_{13} & m_{14} \\ m_{21} & m_{22} & m_{23} & m_{24} \\ m_{31} & m_{32} & m_{33} & m_{34} \\ m_{41} & m_{42} & m_{43} & m_{44} \end{pmatrix}_{x=\tilde{x}} \begin{pmatrix} K - \tilde{K} \\ Z - \tilde{Z} \\ \lambda_S - \tilde{\lambda}_S \\ p - \tilde{p} \end{pmatrix} \tag{B.1}$$

where element m_{ij} denotes the corresponding partial derivatives evaluated at steady state. For example,

$$m_{23} \equiv \frac{\partial \dot{Z}}{\partial \lambda_S} = \theta \frac{\partial C_{U,M}}{\partial \lambda_S}|_{x=\tilde{x}} + (1-\theta)\frac{\partial C_{S,M}}{\partial \lambda_S}|_{x=\tilde{x}} + \frac{\partial m}{\partial \lambda_S}|_{x=\tilde{x}}$$

where the partial derivatives are obtained from (2.1a)-(2.1d), (2.4a), (2.4b), (2.7a), (2.8a), and (2.8b). This is a linearized dynamic system with two sluggish variables K and Z and two jump variables λ_S and p. Under our parameterization, it is characterized by two stable eigenvalues (μ_1, $\mu_2 < 0$) and two unstable eigenvalues. As the number of the stable eigenvalues is equal to the number of the sluggish variables, this yields a unique stable transitional path.

The general solution to (B.1) is given by:

$$x(t) - \tilde{x} = A_1 v_1 e^{\mu_1 t} + A_2 v_2 e^{\mu_2 t} \tag{B.2}$$

where the vectors v_1 and v_2 are the eigenvectors associated with the eigenvalues μ_1 and μ_2, respectively. We normalize the eigenvectors so that their first element is 1, i.e. $v_j = (1, v_{2j}, v_{3j}, v_{4j})$, for $j = 1, 2$. The arbitrary constants, A_1 and A_2, are obtained by evaluating (B.2) at time zero, which gives:

$$A_1 + A_2 = K_0 - \tilde{K} \tag{B.3a}$$

$$A_1 v_{21} + A_2 v_{22} = Z_0 - \tilde{Z} \tag{B.3b}$$

We then obtain the solutions for $K(t)$, $Z(t)$, $\lambda_S(t)$ and $p(t)$ by substituting the values of the constants and the eigenvectors into (B.2). The dynamics for other endogenous variables are then calculated using the the equilibrium conditions (2.1a)-(2.1d), (2.4a), (2.4b), (2.7a), (2.8a), and (2.8b).

B.2 Key Equations to Determine the Steady States

Imposing the steady-state conditions and the homogeneity of degree one of the production function, we have the following six equations to determine the steady state values of $\tilde{K}$, $\tilde{N}_S$, $\tilde{m}$, $\tilde{w}_U$, $\tilde{w}_S$ and $\tilde{p}$:

$$\beta + \delta = F_K[\tilde{K}, \frac{\theta}{(1+\eta)}, (1-\theta)\tilde{N}_S, \tilde{m}] \tag{B.4a}$$

$$\tilde{w}_U = F_{(\theta N_U)}[\tilde{K}, \frac{\theta}{(1+\eta)}, (1-\theta)\tilde{N}_S, \tilde{m}] \tag{B.4b}$$

$$\tilde{w}_S = F_{(1-\theta)N_S}[\tilde{K}, \frac{\theta}{(1+\eta)}, (1-\theta)\tilde{N}_S, \tilde{m}] \tag{B.4c}$$

$$\tilde{p}(1+\tau_m) = F_m[\tilde{K}, \frac{\theta}{(1+\eta)}, (1-\theta)\tilde{N}_S, \tilde{m}] \tag{B.4d}$$

$$\beta\tilde{K}[1-i^{-1}(\beta)] = \frac{(1-\theta)}{\eta}\tilde{w}_S[1-(1+\eta)\tilde{N}_S] \tag{B.4e}$$

$$\beta i^{-1}(\beta)\tilde{K} + \theta\frac{(1-\phi)\tilde{w}_U}{(1+\tau_c)(1+\eta)} + (1-\theta)\frac{(1-\phi)\tilde{w}_S(1-\tilde{N}_S)}{(1+\tau_c)\eta} + \tilde{p}\tilde{m} = X(\tilde{p}) \tag{B.4f}$$

Imposing the production function form as in (2.15), we have the following equations to determine $\tilde{Y}$, $\tilde{K}$, $\tilde{N}_S$, $\tilde{m}$, $\tilde{w}_U$, $\tilde{w}_S$ and $\tilde{p}$:

$$\tilde{Y} = \{\alpha(\theta\tilde{N}_U)^\sigma + (1-\alpha)[\omega\tilde{K}^\rho + (1-\omega)((1-\theta)\tilde{N}_S)^\rho]^{\frac{\sigma}{\rho}}\}^{\frac{1-\mu}{\sigma}}\tilde{m}^\mu \tag{B.5a}$$

$$\beta+\delta = (1-\mu)(1-\alpha)\omega\tilde{m}^{\frac{\mu\sigma}{1-\mu}}\tilde{Y}^{\frac{1-\mu-\sigma}{1-\mu}}[\omega\tilde{K}^\rho + (1-\omega)((1-\theta)\tilde{N}_S)^\rho]^{\frac{\sigma-\rho}{\rho}}\tilde{K}^{\rho-1} \tag{B.5b}$$

$$\tilde{w}_U = (1-\mu)\alpha\tilde{m}^{\frac{\mu\sigma}{1-\mu}}\tilde{Y}^{\frac{1-\mu-\sigma}{1-\mu}}(\theta\tilde{N}_U)^{\sigma-1} \tag{B.5c}$$

$$\tilde{w}_S = (1-\mu)(1-\alpha)(1-\omega)\tilde{m}^{\frac{\mu\sigma}{1-\mu}}\tilde{Y}^{\frac{1-\mu-\sigma}{1-\mu}}[\omega\tilde{K}^\rho + (1-\omega)((1-\theta)\tilde{N}_S)^\rho]^{\frac{\sigma-\rho}{\rho}}((1-\theta)\tilde{N}_S)^{\rho-1} \tag{B.5d}$$

$$\tilde{p}(1+\tau_m) = \frac{\mu\tilde{Y}}{\tilde{m}} \tag{B.5e}$$

$$\beta\tilde{K}[1-i^{-1}(\beta)] = \frac{(1-\theta)}{\eta}\tilde{w}_S[1-(1+\eta)\tilde{N}_S] \tag{B.5f}$$

$$\beta i^{-1}(\beta)\tilde{K} + \theta\frac{(1-\phi)\tilde{w}_U}{(1+\tau_c)(1+\eta)} + (1-\theta)\frac{(1-\phi)\tilde{w}_S(1-\tilde{N}_S)}{(1+\tau_c)\eta} + \tilde{p}\tilde{m} = X(\tilde{p}) \tag{B.5g}$$