Intergenerational Effects of Trade Liberalization

Very Preliminary and Incomplete

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Abstract

2002 Pew Global Attitudes survey shows that support for free trade decreases with age, which is a phenomenon previously unexplored by economists. We show that the negative correlation between age and support for free trade can be explained with a model of sectoral mobility; because welfare effects of trade liberalization depend on workers' mobility and mobility depends on age. In the simulations, we consider a dynamic general equilibrium model with heterogeneous agents where agents can choose their sectors to show the differences in sectoral mobility of younger versus older workers; and gradual adjustment of wages and labor allocation in response to a trade shock. We also calculate the welfare effects of a hypothetical trade liberalization in the US metal manufacturing sector (which has been especially vulnerable to trade shocks in the past, the steel industry in particular) on workers from different sectors, age and experience groups.

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1 Introduction

Recent Pew Global Attitudes survey, conducted in 2002, showed that young people are more enthusiastic about free trade compared to older people. This is a phenomenon previously unexplored by economists. Without considering any economic intuition, one could attribute this to old people's being more conservative. However, we find that in the Pew survey, probability of supporting free trade decreases until age of 70 in a linear fashion and does not decrease further after that, but rather increases. This sudden change close to age of retirement suggests an economic motive, rather than psychological, behind workers' position towards free trade.

Imagine that all workers were perfectly mobile across sectors, then all of them would be unanimously better off or worse off after a liberalization. If all workers were absolutely immobile, then there would be clearly distinct winners and losers from free trade; in that case workers' sectors would determine their gain and loss. In reality, mobility costs probably lie between these two extremes and vary across groups. We will show that one important source of variation has to do with the age of affected workers, causing differences in their position towards free trade. We analyze how trade liberalization affects younger and older workers differently using estimates from a dynamic sectoral choice model with mobility costs in a general equilibrium context.

In particular, we simulate a hypothetical trade liberalization in the metal manufacturing industry using estimated parameters from the structural model discussed in Artuc (2006a). The metal sector is chosen because it has been especially vulnerable to trade shocks in the past, particularly affecting the steel industry in the US. By the introduction of free trade, younger metal workers will be worse off but less worse off compared to older workers, because younger workers are more mobile and can easily find jobs in other sectors. The younger workers in other sectors will be better off, but again less so than many older workers since they are losing their option of working in the metal sector. This varying effect on older workers results in a broader division among older workers in viewing trade liberalization as good or bad. However, very close to retirement people would be less worried about losing their jobs but rather enjoy the decrease in prices with free trade, resulting an increasing support for trade liberalization after a certain age. Thus, in a model of sectoral mobility (where mobility is negatively correlated with age) support for free trade would decrease with age until close to retirement, then would increase again consistent with the Pew survey.

In order to simulate trade liberalization in the metal sector, we will need a dynamic general equilibrium model with overlapping generations. It has to be dynamic because sectoral mobility requires dynamic programming like other discrete choice models, such as Keane and Wolpin (1997). Different from the discrete choice models in the labor literature [with an exception of Lee and Wolpin (2004)] we need a General Equilibrium model since we are interested in workers in other sectors as well. In addition, our general equilibrium approach makes this paper significantly different from displaced workers literature, such as Jacobson, et al. (1993), since we can analyze effects of trade liberalization from a broader aspect in a GE framework.

One important question is why old workers are less mobile than young workers. Previous literature give several different answers to this question, and probably all of them are correct. For example Borjas and Rosen (1980), attributed decreases in mobility with age to increases in wages with tenure. The decrease in mobility with age can be attributed to specific human capital as in Topel (1991), better job match as in Jovanovic (1979) or implicit contracts as in Lazear (1979). Groot and Verberne (1997) suggested that the decrease in mobility with age can be partially attributed to non-financial reasons as well. Unfortunately we will not be able to incorporate all these features in our model at the same time: we assume that workers become less mobile as they get older because they become more likely to hold sector specific human capital as in Neal (1999). In addition, we incorporate an idiosyncratic moving cost parameter changing with age, as in Groot and Verberne (1997).

We aggregate the sectors as we did in the previous paper, Artuc (2006a). The sectors are 1. Construction (which includes construction, mining and agriculture sectors), 2. Manufacturing (excluding metal), 3. Metal manufacturing, 4. Services (excluding trade), 5. Trade (wholesale and retail), 6. Staying at home. The products of these sectors are consumed by the consumers and used as inputs for production as well. Before the trade liberalization, the manufacturing sector is already open to free trade, so we actually mean "trade liberalization and free trade in the metal sector" when we refer to free trade. Other sectors are closed to world trade before and after the trade liberalization, therefore prices adjust endogenously in response to changes in supply and demand (of both producers and consumers). Simultaneous equations related to the supply and demand of products are derived from simple

Cobb-Douglas functional forms. The production functions' parameters are calibrated with Bureau of Economic Analysis data. However, labor supply is calibrated from the estimates of Artuc (2006a) which uses NLSY data [see the appendix for more details]. The labor supply does not have a closed functional form, it is rather an optimization problem of the different types of workers given aggregate parameters. Note that the aggregate parameters are also affected simultaneously from the decisions of the workers.

In our simulations, the adjustment of the economy is quite intriguing: First we assume that with the abolishment of tariffs in the metal sector the prices will decrease about 30%. It is plausible to assume that wages will decrease 30% initially in the metal sector along with the price. However workers will move out of the metal sector to other sectors until wages adjust so that labor supply equals labor demand. Manufacturing sector is also directly affected from free trade because the metal sector product is an important input for manufacturing. With lower input prices manufacturing sector's output increase significantly, pushing wages up. Note that metal is an intermediate good, which is not consumed and has no direct effect on the Consumer Price Index. With the increased output of the second largest sector in the economy (manufacturing), total output increases noticeably, raising demand for non-traded goods such as services. Therefore, the prices in the economy in general increase with the increased demand, causing Consumer Price Index (henceforth CPI) to increase, making metal workers even more worse off. This adjustment process causes broad division among workers of different age and experience groups. In the next sub-section findings from Pew Global Attitudes survey will be summarized, then we will continue with the model.

Pew Global Attitude Survey

Pew Global Attitudes survey is consist of interviews conducted in 44 countries with 38,263 individuals in 2002. It includes approximately 100 questions on various popular issues and personal background. We are not going to use the survey data to estimate the main model but to illustrate our motivation for this research: A question on international trade points out a very interesting yet unexplored issue. The question is: "And what about the different products that are now available from different parts of the world - do you think this is a very good thing, somewhat good, somewhat bad or a very bad thing for our country?" We find that as people get older they are less likely to answer this question as "good" and "somehow good". We set up a simple probit model to demonstrate the correlation between age and

Table 1: Simple Probit Model

	Constant	*Age*	*Age*^{2}	*Age*^{3}	*Female*	*Emplyd*
Estimate	-0.300	-0.008	0.000	-0.000	-0.020	0.053
Standard Error	(-14.57)	(-2.45)	(0.001)	(-0.21)	(-1.42)	(3.51)

Table 2: Probability of Support

Age	20*s*	30*s*	40*s*	50*s*	60*s*	70*s*	80*s*
Percent of A=1	37.38	35.33	31.58	30.23	27.70	23.83	24.16

probability of supporting free trade.

Consider that $A = 1$ if the individual answers the question as "good" and else $A = 0$. We assume that $A = 1$ if and only if gains from trade u is greater than a certain threshold $\bar{u}$. We use a simple linear form

$$u = \beta_0 + \beta_1 Age + \beta_2 Age^2 + \beta_3 Age^3 + \beta_4 Female + \beta_5 Employed + \varepsilon,$$

Where ε is a iid shock, *Employed* is a dummy for employment status and *Age* means age in last birthday minus eighteen. Estimates show that gains from trade decrease with age, see Table 1 for the estimates and Table 2 for the probability of answering as "free trade is good". In the next section we will set up a general equilibrium model to explain why age and gains from trade are correlated.

2 Model

Our ultimate goal is to simulate trade liberalization in metal sector to see if we can explain the correlation between age and support for free trade with a model of sectoral mobility. After the introduction of free trade, average wages in sectors will change, making some workers better off and some worse off. In general, wages in the metal sector will decrease and wages in other sectors will increase. The main goal of the policy simulation is twofold: first, to calculate average wages, prices and outputs over the transition; and second, to calculate value functions of workers using the average wages. If wages, prices and outputs were known then calculating value functions would be straightforward similar to the estimation. Note that we used average wages from CPS for the estimation in Artuc (2006a), which is exogenous to the workers' individual optimization problem. For the policy simulation, however, wages, prices and outputs need to be endogenous to trade policy and labor flows. The value functions of workers are functions of average wages and the average wages are functions of value functions. Similar stories apply to price levels and outputs. Calculating wages, outputs, prices and value functions simultaneously is much more burdensome than calculating value functions alone. To ease the computational burden, I will assume a simplified version of Model 2.1of Artuc (2006a), (with smaller state space) for calculating average wages [see the appendix for more details]. Once average wages are known I will use the actual Model 2.1 to calculate the value functions of workers. First, I will introduce basic supply and demand relations for the general equilibrium model with structural labor supply.

2.1 Consumers and Demand

Consumers are identical and have a Cobb-Douglas utility functions,

$$U_t^j = \prod_{i=1}^{I-1} \left(x_t^i\right)^{a_i} + \zeta^j, \tag{1}$$

which leads to the money-metric utility function described in Artuc (2006) Model 2.1 (which is $U_t^j \propto w_t^j + \upsilon^j + u_t^j$); where x_t^i is the sector i product,[2] consumed at time t, $\sum_{i=1}^{N} a_i = 1$, ζ^j is the random idiosyncratic utility derived from working in sector j. Therefore the consumer price index can be calculated as:

$$CPI_t = \prod_{i=1}^{I-1} \left(p_t^i\right)^{a_i}. \tag{2}$$

For traded goods the price level is exogenous: $p_t^i = p_i^W + \tau_i$, where p_i^W is the world price and τ_i is the tariff rate. For non-traded goods price level is endogenous:

$$p_t^i = \frac{M_i}{q_t^i}, \tag{3}$$

where q_t^i is the total amount of product produced and M_i is the share of income in the economy spent on the product both by consumers and producers which can be calculated

[2]Some sectors' proucts are not consumed but only used as inputs, such as Metal sector's product.

simply by exploiting the the Cobb-Douglas nature of the economy:

$$M_i = a_i \sum_{j=1}^{I-1} \left(b_6^j + b_7^j\right) q_t^j p_t^j + \sum_{j=1}^{I-1} b_i^j q_t^j p_t^j, \tag{4}$$

where b_i^j's are parameters taken from Cobb-Douglas production functions which will be explained in the next section. Note that savings are not allowed in this simple economy. The details of the calibration method are described in the appendix.

2.2 Production and Labor Demand

Production functions are Cobb-Douglas and the real wage, w_t^i, is assumed to be the real marginal product of effective human capital possessed by workers. The production function is defined as:

$$\begin{aligned} q_t^i &= A^i \left(L_t^i \bar{h}_t^i\right)^{b_6^i} \left(K^i\right)^{b_7^i} \prod_{j=1}^{I-1} \left(x_t^{j,i}\right)^{b_j^i}, & (5) \\ &= B^i \left(L_t^i \bar{h}_t^i\right)^{b_6^i} \prod_{j=1}^{I-1} \left(x_t^{j,i}\right)^{b_j^i}, & (6) \end{aligned}$$

where A^i is a coefficient of productivity, L_t^i is the total number of workers in sector i, $\bar{h}_t^i$ is the average human capital level of individuals working in that sector, similar to the general convention K^i is the capital level which is assumed to be fixed, $x^{j,i}$ is the j sector product used in i's production. Since capital is fixed we can define another coefficient for convenience, $B^i = A^i \left(K^i\right)^{b_7^i}$. Shares of labor in the production functions are calibrated to match the shares of labor in gross domestic product in each sector. Initially, all prices are normalized to be unity and the fixed coefficient, B^i, is calibrated such that productions in each sector roughly match sectoral gross domestic products. Thus the wage equation can be derived as:

$$\begin{aligned} w_t^i &= \frac{p_t^i}{CPI_t} A^i b_6^i \left(L_t^i \bar{h}_t^i\right)^{b_6-1} h_t^i \left(K^i\right)^{b_7^i} \prod_{j=1}^{I-1} \left(x_t^{i,j}\right)^{b_j^i}, & (7) \\ &= \frac{p_t^i}{CPI_t} B^i b_6^i \left(L_t^i \bar{h}_t^i\right)^{b_6^i-1} h_t^i \prod_{j=1}^{I-1} \left(x_t^{i,j}\right)^{b_j^i}. & (8) \end{aligned}$$

where p_t^i is the price level and L_t^i is the number of workers in the sector. Parameters for

Table 3: Input Matrix (b_j^i)

	Const	*Manuf*	*Metal*	*Service*	*Trade*
Const	0.08	0.07	0.05	0.02	0.00
Manuf	0.23	0.35	0.07	0.06	0.04
Metal	0.05	0.05	0.29	0.00	0.00
Service	0.18	0.17	0.14	0.24	0.29
Trade	0.06	0.06	0.07	0.01	0.02
Labor	0.26	0.16	0.25	0.37	0.37
Capital	0.14	0.15	0.12	0.31	0.27

labor demand equations, B^i and b_j^i are calibrated using data from the Bureau of Economic Analysis. The details of the calibration method are described in the appendix. The shares of inputs are summarized in Table 3.

3 Labor supply

I assume that workers stay in the market for 40 years. Therefore a worker can get a maximum of 40 years of sectoral and market experience. I discretize the state space so that market and sectoral experience can only take q values. Note that a worker's market experience is at least as large as her sectoral experience. Hence, the size of the state space is $TI\left(q^2+q\right)/2$, where I is the total number of sectors, and T number of years required for the transition from autarky steady state to free trade steady state. A worker ages with probability $\gamma = q/40$ in each period. If we consider all possible combinations of sectoral and market experience and a thirty year transition, then the size of the state space would be $30 \times 6(40^2 + 40)/2 = 147600$ and a worker would age in each period with probability $\gamma = 1$, as in reality.

Each worker chooses her sector similar to the Basic Model 2.1, with the decision set as in (13), so it includes five sectors and a non-market sector (staying at home). The state-space, however, is simplified to ease the computational burden

$$s_t^n = \left[d_{t-1}^n \quad SecExp_t^{nd_t^n} \quad MktExp_t^n \right]', \tag{9}$$

where market experience $MktExp_t^n \in \{5, 15, 25, 35\}$ and sectoral experience $SecExp_t^{nd_t^n} \in \{5, 15, 25, 35\}$. Note that sectoral experience is less than or equal to market experience by definition $MktExp_t^n \geq SecExp_t^{nd_t^n}$, therefore the size of the state space is 1800 (assuming

Table 4: Worker types

Type	I	II	III	IV	V	VI	VII	$VIII$	IX	X
$MktExp$	5	15	15	25	25	25	35	35	35	35
$SecExp$	5	5	15	5	15	25	5	15	25	35
Age	25	35	35	45	45	45	55	55	55	55

Table 5: Transition Probabilities, $\Pr(s^r_{t+1}|s^n_t)$

	I	II	III	IV	V	VI	VII	$VIII$	IX	X
$d_{t+1} = d_t, Pr = 0.9$	I	II	III	IV	V	VI	VII	$VIII$	IX	X
$d_{t+1} = d_t, Pr = 0.1$	III	V	VI	$VIII$	IX	X	$-$	$-$	$-$	$-$
$d_{t+1} \neq d_t, Pr = 0.9$	I	II	II	IV	IV	IV	VII	VII	VII	VII
$d_{t+1} \neq d_t, Pr = 0.1$	II	IV	IV	VII	VII	VII	$-$	$-$	$-$	$-$

$T = 30$), and there are ten types of workers in the economy differentiated by their age and experience.

In each period, the probability of aging (gaining experience) is $\gamma = 0.1$. For example, a type III worker becomes type VI with probability γ in each period (if she stays in her sector). In addition, if a worker changes her sector, her sectoral experience drops to the minimum level, which is 5 years. For example, if a type III worker changes her sector, she becomes type II. If a worker with 35 years of market experience ages, she receives a lump sum payment[3] and exits the market, and a worker with 5 years of experience enters the system.

The wage equation is also simplified and defined as

$$w_t^{ni} = \frac{\bar{w}_t^i}{\bar{h}_t^i}\left(\phi_6^i + \phi_4 SecExp_t^{ni} + \phi_5 MktExp_t^n + z_t^{ni}\right), \tag{10}$$

where the constant[4] ϕ_6 is a weighted average of ϕ_1, ϕ_2 and ϕ_3. The equations (13), (18), (21), (17), (20) and (21) from Model 2.1 are still relevant for this model. Note that the parameters, C_0, C_1, C_0/σ_e, ϕ_4, ϕ_5, ϕ_6^i, υ^1, υ^2,...,υ^6 are taken from the estimates of Model 2.1 [see the appendix for details].

Labor Allocation in Sectors:

The number of workers in sector i is equal to the sum of all types of workers, $L_t^i =$

[3]The lump-sum payment is equal to 10 years' discounted average wage, which is equal to 8.0.

[4]I assume that all workers have the same level of education. Education only effects workers' decison to stay at home or work, it does not effect workers' decison on which sector to work. Because education increases wages offers from all sectors by the same amount.

$\sum_{n=1}^{10} L_t^{ni}$. I consider a continuum of workers where $\sum_{i=1}^{6} L_t^i = 1$. I assume that probability of a type n worker choosing sector j if she is in sector i is defined as

$$m_t^{nij} = E_z \frac{\exp\left[\left(E_u V_{t+1}^j - E_u V_{t+1}^i - C^{i,j}\right)/\nu_e\right]}{\sum_k \exp\left[\left(E_u V_{t+1}^k - E_u V_{t+1}^i - C^{i,k}\right)/\nu_e\right]},$$

where $\nu_e = \sqrt{6}\sigma_e/\pi$ and the alternative specific value functions are

$$V_t^i = U_t^i\left(s_t^n, u_t^n, z_t^n\right) + \beta \sum_{r=1}^{10} \Pr\left(s_{t+1}^r | s_t^n\right)\left[\Omega_t^i\left(s_{t+1}^r\right) + E_{u,z} V_{t+1}^i\left(s_{t+1}^r, u_{t+1}^r, z_{t+1}^r\right)\right].$$

The labor allocation equation is

$$L_{t+1}^{nj} = \sum_{r=1}^{10} \tilde{P}\left(s_{t+1}^n | s_t^r\right) \sum_{i=1}^{6} L_t^r m_t^{rij}, \tag{11}$$

where $\tilde{P}\left(s_{t+1}^n | s_t^r\right)$ is the transition probability for labor allocation. Note that the transition probability for labor allocation, $\tilde{P}\left(s_{t+1}^n | s_t^r\right)$ needs to be defined differently from the actual transition probability, $\Pr\left(s_{t+1}^n | s_t^r\right)$, so that the number of workers in the system does not change. For example, a young worker enters the market when another worker retires, therefore $\tilde{P}(I|VII) = 0.1$, $\tilde{P}(I|VIII) = 0.1$, $\tilde{P}(I|IX) = 0.1$ and $\tilde{P}(I|X) = 0.1$ and for all other types $\tilde{P}\left(s_{t+1}^n | s_t^r\right) = \Pr\left(s_{t+1}^n | s_t^r\right)$. However, the probability of an old worker becoming young is still zero, $\Pr(I|VII) = 0$, $\Pr(I|VIII) = 0$, $\Pr(I|IX) = 0$ and $\Pr(I|X) = 0$.

3 Simulation Results

One year's average real wage is approximately 1 in the economy, so all numbers presented here could be considered relative to this wage level. Also note that, the label "Young" is used for workers with 5 years of sectoral and market experience; "Old 1" for workers with 5 years of sectoral experience and 35 years of market experience; and "Old 2" for workers with 35 years of sectoral and 35 years of market experience.

The economy consists of six sectors, 1. Construction, agriculture and mining, 2. Manufacturing except metal 3.Metal manufacturing, 4. Service except Trade 5. Wholesale and retail trade, 6. Staying at home. The sectors will be labeled as Construction, Manufacturing, Metal, Service, Trade and Home respectively, using the largest industry's name in each

Table 6: Steady State Percentage of Workers

Type	I	II	III	IV	V	VI	VII	$VIII$	IX	X
$MktExp$	5	15	15	25	25	25	35	35	35	35
$SecExp$	5	5	15	5	15	25	5	15	25	35
Autarky	25%	10%	15%	5%	7%	13%	5%	2%	6%	12%
Free Trade	25%	10%	15%	4%	7%	14%	4%	2%	6%	13%

sector.

Initially we assume that all prices are equal to 1, and we calibrate the parameter B^i so that average wages in sectors under autarky are equal to average wages observed in CPS. Note that we mean autarky in metal sector when we use the term "autarky"; and similarly "free trade" means free trade of metal sector product. For other sectors, the trade openness is not changing through the policy simulation: we assume that Manufacturing product is traded so the world price, 1, is taken exogenously, but Construction, Service and Trade sector prices are calculated endogenously given the change in demand and production, using equations (3) and (4).

In autarky, metal is not traded and the equilibrium price is 1. Then at the end of time zero we assume that the government announces free trade for the metal sector (a shock therapy) which will be in effect by the beginning of time 1, where the time unit can be considered as one year. We assume that world price is 0.7 for this product. Then ,we analyze how wages, labor allocation, output and prices adjust after this free trade announcement (given the set of simultaneous equations of workers' and producers' decisions as described in section 2).

Gross Flows

Figures 1.1-6 illustrate the ratio of workers who leave their sector over years. After the announcement of free trade metal workers anticipate the wage decrease (which would be 30% if they do not react), therefore the number of all types of workers moving from the metal sector to other sectors increase at time zero. Of course, the opposite of this story is observed in all other sectors except Home.

There are two particularly interesting sectors other than metal. The first one is manufacturing, because we see a much larger decrease in out-flows in this sector compared to others, which means that manufacturing workers are much better off after the announcement. We will discuss the reasons for this difference later on, but it is obvious that the real wages increase relatively more in this sector. Also note that the workers have perfect foresight in our model (since it is a rational expectations model with no aggregate uncertainty except the trade liberalization in the metal sector), which means that workers see that they will be better off if they stay in the manufacturing sector and they act upon it. However, because of the individual shocks some workers still decide to move, thus net flows are not equal to gross flows.

The other interesting sector is Home; because we see that the out-flows of young workers increase while the out-flows of old workers decrease at the same time. This means that working provides more utility after free trade for young workers and less utility for older workers: a hint indicating that unexperienced old workers will be worse off in general after free trade. Finally, note that older workers' flows out of the Home sector are smaller compared to younger workers, indicating that they will take longer to find new jobs in the other sectors if they lose their job because of free trade.

Labor Adjustment

See Figures 2.1-6 for the illustrations of labor adjustments. These are directly derived from gross flows explained in the previous paragraph. We see major changes in only two sectors: Metal and Manufacturing. The metal sector shrinks about 60%, consistent with the trade liberalization and decrease in the product price. Most of the labor adjustment in the metal sector takes place in the first five years: we observe that the labor allocation completes 94% of the distance between autarky allocation and free trade allocation. For the Service sector this number is 83%, for the manufacturing sector it is 89%, and it is 60% for the Home sector. Note that most of the sectors' steady state labor allocations are almost unchanged after free trade (except Metal and Manufacturing). It is obvious that the Metal sector would be significantly affected, however this is not obvious for the Manufacturing sector, which we turn to in the next subsection.

Another intriguing point is the presence of ridges in the labor allocation graphs of Construction, Trade and Staying home sectors (Figures 2.1, 2.5 and 2.6). In these sectors we see that the number of workers continue to increase until time 5, then it slowly decreases, however in the steady state this number is still larger than in the autarky steady state (it does not decrease further). First of all, we have to note that these changes are relatively small: at any given time, the number of workers is not more than 1% different from any other point in time. For the Staying home sector, the explanation is quite straightforward: Metal workers choose to stay at home since moving to Home sector is costless and they have less incentive to work in their original sector. Hence, we see a large flow from Metal sector to the Home sector, and workers who stay home slowly move out as they receive attractive shocks from other sectors. So the first 5 time periods are mainly characterized by large out-flows from the metal sector. The utility of being in the Metal sector decreases so much that, most of the Metal workers just move out as they receive any acceptable offer from any sector. Although moving to market sectors (Construction, Manufacturing, Metal, Service and Trade) is costly, the same story applies, most of the metal workers move out as soon as they receive a reasonable shock from any sector. Being in the metal sector is undesirable for most of the workers, so they move out right away to any sector that sends good shocks. However, being in the Manufacturing sector seems to be the most desirable; so those workers who move to Trade and Staying at home sectors from the Metal sector move again, but this time to the Manufacturing sector if they receive a good offer.

Output

Output levels relative to autarky output levels, q_t^i/q_0^i, are illustrated in Figures 3.1-6. First of all, the metal sector output decreases 60% after free trade, as a result of a decrease in the price level and out-flow of workers. There are two sectors primarily affected from this price decrease: Manufacturing and Construction. Note that Metal is used primarily in producing itself, it has 30% share among all inputs. Other than that, it is used in Manufacturing and Construction, 5% and 4% shares in inputs respectively. Therefore the decrease in the input price increases the production of Manufacturing about 10% and Construction about 3.5%. Other sectors are not significantly affected, we see a 1% increase in the Service output and 0.5 increase in the Trade output. As a result the total output increases by about 2.5%. There are two interesting points that will be explained in the next paragraph: 1. Why Construction output does not increase as much as the Manufacturing output? 2. Why the Trade output continuously increases although the number of workers decrease after time period 5?

Prices

Illustrations of price adjustments are presented in Figures 4.1-6. The price level in the Metal sector decreases from 1 to the world price level (which is 0.7) as the government abandons the tariffs for that sector. The Manufacturing sector takes the world price, which is 1 for that sector even in autarky, because free trade is allowed for the Manufacturing product at all times and the term autarky is actually used for the Metal sector. Other sectors' products are not traded so demand and supply jointly determine the price levels. Note that all non-traded products are demanded by both producers and consumers. We keep track of outputs and price levels in our simulations, as they are determined simultaneously along with the values of workers, (see the appendix for details on the solution method).

Here is a simplified explanation of supply and demand relations after the trade liberalization: First, the price of metal decreases. Metal is used as input in the Manufacturing and Construction sectors, therefore the supply of these products increases along with the reduced input price. In the Manufacturing sector, the supply increases significantly since the price level is exogenous and inelastic. However, the Construction sector price is endogenous: an increase in supply reduces the price and limits further increase in supply. With the increased output in these two sectors (especially with the large increase in the Manufacturing sector which is very large), the total output increases. Thus, the demand for all products increases, causing the prices of non-traded products to increase, which in turn increases the output in the non-traded sectors. Note that even if the number of workers decreases slightly after the initial jump in the Trade sector, the output continues to increase further because the relative price of Manufacturing input is much lower. All these price increases raise the CPI. Note that the decrease in the Metal sector product has no direct effect on CPI since metal is only used as an intermediate good, and not consumed by agents.

Wages

Real wages are determined jointly by the effective number of workers and the price levels. The evolution of wages is described in Figures 5.1-5. The real wages decrease in the Metal sector, and increase in all other sectors as one might expect. Because of large out-flows from the Metal sector, we observe ridges in the first five years after the trade liberalization. In the metal sector real wages increase slightly since the number of workers continues to decrease, increasing marginal product of labor. In all other sectors wages decrease slightly in the first five years (the periods with large out-flows from the Metal sector) but afterwards they continue to increase in the non-traded sectors (Construction, Service and Trade) due to continuously increasing prices, parallel to the output increases in the Manufacturing sector, which is not matched by the other sectors. This increase in output increases the demand for non-traded output and the increase in output is small causing an increase in prices, thus increasing the wages.

Welfare of Workers

Welfare of workers is shown in Figures 6.1-6. Note that a Young worker is a worker with 5 years of sectoral and market experience (Type I), Old 1 is a worker with 5 years of sectoral and 35 years of market experience (Type VII), while Old 2 is a worker with both 35 years of sectoral and market experience (Type X). The figures show the changes in the present discounted utility after the trade liberalization. Note that one year's average wage is about 1.0, therefore a change of -0.5 is equivalent to losing 6 months salary right away with no further decrease in future salaries. So the numbers do *not* refer to equivalent percentage wage losses as used in the displaced workers literature; they should be considered as one time losses.

Let us start the analysis with the Metal sector (Figure 6.3): as one might expect, all workers are worse off by the trade liberalization. The workers who are most affected are the Old 2 type workers since they were enjoying higher wages compared to others because of their high sectoral experience. If we compare them with the Young workers, we see that they differ from 3 aspects: first, they have more sectoral experience which causes them to lose more; second, they have higher non-pecuniary mobility costs which makes it more difficult for them to find new jobs; third, their time horizon is shorter which might make them less worse off since they would be subject to negative effects of free trade for a shorter period of time. Shorter time period also means that they are closer to retirement, increasing CPI decreases the purchasing power of their retirement savings. Hence the effect of shorter time period is ambiguous: it might increase or decrease the negative effects of trade liberalization. Figure 6.3 indicates that Old 1 is slightly more worse off (-0.8) compared to Young (-0.5), while Old 2 is a lot more worse off (-2.0). These values cannot directly be compared with the results of the literature on displaced workers, since they only consider wage decreases. For example, Jacobson LaLonde and Sullivan (1993) report that tenured workers might lose 25% of their wage continuously due to displacement. That would be equivalent to 210% percent one time loss of one year's wage which is very close to my findings. Note that I use present discounted welfare derived from utility functions, therefore my analysis also includes non-wage components of the utility as well.

Different from the displaced workers literature, I can use the welfare effects of trade liberalization in the metal sector on the other sectors as well. For example Figure 6.2 shows that the welfare of manufacturing workers increases proportionally to their sectoral and market experience. Old 1 workers with 35 years of sector and market experience gain about 0.25, while Old 2 workers gain only 0.1 and Young workers gain about 0.02. This graph is almost like a mirror image of the graph of Metal worker's welfare change (Figure 6.3).

Young workers in the metal sector do not experience high costs since they are very mobile and can easily find new jobs in the other sectors. Likewise, young workers in the Manufacturing sector do not experience high benefits (compared to older workers) since they are very mobile and their option value of moving and working in the metal sector decreases significantly. We call this a "mirror effect". Note that wages are almost unchanged in other sectors.

On the other hand, the welfare effects in the non-traded market sectors are more variant (see Figures 6.1, 6.4 and 6.5). Young workers are unanimously better off, but by a small amount ranging between 0.01 and 0.03. Note that their option value does not decrease as much as the Manufacturing workers' option value, because the increase in wages in the Manufacturing sector compensates the decrease in wages in the Metal sector (for their option values). Old 1 workers are unanimously worse off ranging between -0.04 and -0.06. The reason for their being worse off is the increase in the CPI, which decreases the purchasing power of their retirement benefits, while the increase in the real wages partially compensates this decrease, although it is not sufficient to completely take it away. Old 2 workers are slightly better off in the Construction and Service sectors (0.02 and 0.03) and slightly worse off in the Trade sector (-0.02). This difference is caused by the differences in the initial increases in wages: note that the wage increase in the Trade sector is gradual. Old 2 workers in the Service and Construction sectors enjoy an increased wage sufficient to compensate for the increase in the CPI (which reduces the purchasing power of their future retirement benefits).

We see that older workers gain (or lose) an amount ranging between -2.0 to +0.25. Young workers gain (or lose) an amount ranging between -0.5 to +0.1. Hence welfare effects of tariff reduction in the metal sector shows a wider range on older workers, creating larger losses and benefits among them, consistent with the findings of the Pew Global Attitudes Survey.[5]

Experience and Welfare

After we calculate the wage flows we can use the model from Artuc (2006a), Model 2.1, to calculate how each worker is affected by trade liberalization. Note that the reason we assumed only 10 types of workers in this chapter was to restrict the state space, since endogeneity of wages increase the state space tremendously. If the wages were known, we could have used directly Model 2.1, as we did for the estimation in Artuc (2006a). Therefore after calculating the wage flows, we can calculate values of the workers the same way we did for the estimation without worrying about the size of the state space. The change in workers' values are illustrated in Figures 7.1-5 and Figures 8.1-5.

There are three main factors affecting workers' attitudes towards free trade: first, moving costs and value of outside options; second, number of years to work; and third, changes in CPI. Workers in the metal sector are hurt more if they are less mobile because it is more difficult for workers with limited mobility to find new jobs in other sectors. Note that the value of the outside option increases significantly for the metal workers.

Workers in the Manufacturing sector are helped more if they are less mobile because their probability of working in the metal sector is smaller compared to the workers with high mobility. Note that since the wages in other sectors do not change much, the more mobile a worker is the more her outside option decreases after free trade because of the decrease in the Metal sector. Therefore in the Manufacturing sector a worker's being better off is negatively correlated with her mobility. Hence, high moving cost increases the positive effects of free trade if the outside option decreases because of the decrease in the Metal sector wages. Similarly, high moving cost increases the negative effects of free trade in a sector if the wages in that sector decrease because of free trade.

On the other hand, this explanation does not apply to sectors other than Manufacturing since their outside option does not decrease at all, because of the significant increase in the Manufacturing wages. In those sectors, positive effects of trade liberalization decrease with age as workers get closer to their retirement, since the purchasing power of their retirement

[5] Note that the question in the survey is on free trade general not on a particular sector as I studied in this research. Young metal workers can easily be made better off by a multi-sector trade liberalization since they are not significantly worse off. On the other hand, older metal worker will unlikely be better off even if there were other sectors opening up for free trade.

compensation decreases. On the other hand positive effects of trade liberalization increase with sectoral experience since workers enjoy higher increase in their wages. Note that especially in Service and Trade sectors the sectoral experience has little effect as the wage changes are very small in these sectors.

Change in Present Discounted Value of Wage Flows

Note that some papers in the literature consider firing cost rather than mobility costs, as in Utar (2005) and Kambourov and Manovskii (2003). The mobility costs mentioned in this paper may include firing cost as well as any other unmodelled frictions. Therefore one might argue that the changes in workers' utility might be different with a different set of assumptions. Fortunately, this model imitates the labor flows well no matter where these frictions come from. Note that we studied different assumptions on these frictions in Artuc (2006a).

We consider changes in the present discounted value of expected wages as a proxy of the changes in utility. Unlike the utility, changes in the wages are not affected by the assumptions on the source of frictions. Therefore, by showing that there are similarities between the qualitative effects of trade liberalization on present discounted utility and present discounted wages, we show that the qualitative implications of the model are robust for any given assumption on frictions.

Consider the present discounted value of expected wage flows, $\tilde{V}_t^i$, given as

$$\tilde{V}_t^i = w_t^i + \sum_{j=1}^{I} m_t^{ij} \tilde{V}_{t+1}^j. \tag{12}$$

The change in $\tilde{V}_t^i$ values after the trade liberalization are illustrated in Figure 9.1-5. Note that these figures look very similar to Figures 7.1-5, which explain the changes in the utility, V_t^i. Naturally, the numbers differ especially for the Metal sector. So we conclude that the quantitative implications of the model may be affected by the assumptions on the sources of friction

Finally, Figures 11.1-5 show the percentage changes in the expected wages. Note that our results are comparable with the previous "displaced workers literature", our finding for workers around 55 years old who lose 25% of their wage, is similar to what Jacobson LaLonde and Sullivan (1993) reports for experienced workers.

3.4 Conclusion

We find that, in case of free trade in the metal manufacturing sector, younger metal workers will be hurt but less so than older workers. The younger workers in other sectors will be helped more than most of the older workers. However, older workers with large sectoral experience in the manufacturing sector will be better off than all young workers in the economy, while most of the old workers in the economy without sectoral experience will be worse off. This varying effect on older workers results in a broader division among older workers in viewing trade liberalization as good or bad than among younger workers, consistent with the findings of the Pew Global Attitudes Survey. The results also show that displaced younger metal workers can find new jobs in other sectors faster than older workers if they lose their jobs because of free trade. Increasing mobility costs by age suggests that non-monotonic age-correlated benefits in the Trade Adjustment Assistance program may yield a more efficient compensation scheme.

The main finding of the paper is: old workers are more split and young workers are more unanimous in seeing free trade as good or bad. The results might be different for different simulation exercises. In this exercise we liberalized a sector which produces an intermediate good, which has no direct effect on CPI. If we were studying a liberalization of the manufacturing sector the results would be different: we could see more workers being better off, parallel with the decrease in CPI. The main finding, which is the unanimity of younger workers in general, would be unchanged.

Incorporating capital mobility in the model in addition to worker mobility would allow us to study the welfare effects of free trade more precisely, especially over the long run, a task which is left for future research. The simulations predict that displaced metal workers' attempts to find new jobs in other sectors will be slow, leading to a temporary rise in unemployment. Pissarides (1985) type searching agents could be used to study how free trade changes the unemployment rate in the long run, a task which is also left for future work.

Appendix

Summary Model 2.1 from Artuc (2006a)

Assume that there are 6 sectors[6] in the economy with a total of N workers. Workers choose a sector in which to work in each period. If a worker indexed by n decides to work in sector i then $d_t^n = i$ where

$$d_t^n \in \{1, 2, 3, 4, 5, 6\}. \tag{13}$$

I will define the sectors below. A worker, n, receives wage w_t^{ni} from working in sector i, with the wage equation[7] given by

$$\begin{aligned} h_t^{ni} &= \phi_1 + \phi_2 HighSch^n + \phi_3 College^n + \phi_4 SecExp_t^{ni} + \phi_5 MktExp_t^n + z_t^{ni}, \quad (14) \\ w_t^{ni} &= \frac{\bar{w}_t^i}{\bar{h}_t^i} h_t^{ni}, \end{aligned}$$

where h_t^{ni} is the human capital level for individual n, $\bar{w}_t^i$ is the average wage in sector i and $\bar{h}_t^i$ is the average human capital level in the sector, z_t^{ni} is a mean-zero random shock distributed "normal" with variance σ_z^2, $SecExp_t^{ni}$ is the sector specific experience,[8] and $MktExp_t^n$ is market experience (defined as age minus schooling). The workers who stay at home do not receive any wage, $w_t^{n6} = 0$. See the Appendix for details on deriving the wage equation. Different from KW, I assume that all sector specific experience is lost if a worker changes her sector. Even if she returns to her initial sector she has to start over from zero sectoral experience. Without this assumption the state space would be extremely large.[9] Attending high school as final degree is denoted as $HighSch$ and college is denoted as $College$.[10] Sectoral experience evolves as

$$\begin{aligned} \text{if } d_t^n &= d_{t-1}^n \implies SecExp_t^{ni} = SecExp_{t-1}^{ni} + 1, \\ \text{else if } d_t^n &\neq d_{t-1}^n \implies SecExp_t^{ni} = 0. \end{aligned}$$

[6] 1. Agriculture, Construction and Mining, 2. Manufacturing except Metal, 3. Metal, 4. Service {Transportation, Public Utilities, Communication, Finance, Insurance, Real Estate, Repair, Personal, Entertainment, Professional Service, Public,etc.} 5. Trade {Wholesale and Retail}. 6. Staying at Home.

[7] Although my formulation of the wage equations is different from the previous literature it yield to a wage tenure profile consistint with the previous literature, such as Topel (1991).

[8] Neal (1995) shows that firm specific experience contributes little to the observed slope of wage tenure profiles when sectoral experience is accounted for.

[9] In the next subsections, I improve the model from other aspects such as time persistent preference shocks, which also makes the state space large. It would be infeasible to consider complicated history of choices, as in KW, and time persistent shocks at the same time.

[10] In the next version, I will consider different returns for schooling for different sectors, which will increase the number of parameters to estimate. Note that these options are mutually exclusive since they are defined as final degree. Unlike KW, I do not model how workers decide how much schooling to obtain, therefore I do not use individuals who did not complete their education to prevent bias in the estimation.

In addition to the wage, each worker n receives an idiosyncratic random utility u_t^{ni}, and a fixed utility υ^i from working in sector i. Hence the total utility of being in sector i, is

$$U_t^i(s_t) = w_t^i(s_t^n, z_t^n) + \upsilon^i + u_t^{ni}, \tag{15}$$

where wage, $w_t^i(s_t^n, z_t^n)$ is a function of the state variables and a random shock for the worker. The state vector s_t depends on education and experience such that

$$s_t = \begin{bmatrix} d_{t-1}^n & HighSch^n & College^n & SecExp_t^{nd_{t-1}^n} & MktExp_t^n \end{bmatrix}'. \tag{16}$$

The fixed utility υ^i is the same for all workers in an industry while the random variables z_t^{ni} and u_t^{ni} vary across workers.[11] Linearity of components of the utility function ensures agents will be risk neutral so that I do not need to model savings. I assume that random component of utility, u_t^{ni}, is distributed as "extreme value" with variance σ_u^2:

$$\begin{aligned} u_t^{ni} &\sim EV(0, \sigma_u), \\ z_t^{ni} &\sim N(0, \sigma_z). \end{aligned} \tag{17}$$

Workers will incur a moving cost, C, if they change their sectors, so $C^{d_t^n, d_{t+1}^n} > 0$ if $d_t^n \neq d_{t+1}^n$ and $C^{d_t^n, d_{t+1}^n} = 0$ if $d_t^n = d_{t+1}^n$. In this version of the model I will include "Staying at Home" as a non-market sector and assume that it is costless to chose the non-market sector, so $C^{d_t^n, d_{t+1}^n} = 0$ if a worker chooses to stay at home in period $t+1$. I model the moving cost as a linear function of age[12]:

$$\begin{aligned} C^{d_t^n, d_{t+1}^n}(s_t^n) &= 0, \text{ if } d_t^n = d_{t+1}^n \text{ or } d_{t+1} = 6, \\ \text{else } C^{d_t^n, d_{t+1}^n}(s_t^n) &= C_0 + C_1(Age_t^n - 14). \end{aligned} \tag{18}$$

All workers are expected to live for a fixed amount of time, T. Hence the objective of an individual for any time $t = 1, ..., T$ is to maximize her present discounted total utility as in Bellman (1957):

$$V_t(s_t^n) = \max_i \left(V_t^i(s_t^n)\right), \tag{19}$$

[11] I incorporated random effects to the model in another version which increases the state space significantly. The new version of the model is currently being estimated, and the results will be presented in the next version of the paper.

[12] For estimation and simulation purposes we assume that the linear increase in the non-pecuniary moving cost, C, stops after the age of 32. We found that this assumption is consistent with the implied probabilities of sector change for different age groups from CPS. See the data section (2.3) for more details.

where sector (alternative) specific value functions are:

$$V_t^i\left(s_t^n,u_t^n,z_t^n\right) = U_t^i\left(s_t^n,u_t^n,z_t^n\right)+E\max_j \beta\left\{V_{t+1}^j\left(s_{t+1}|s_t\right)-C^{i,j}\left(s_t^n\right)\right\}, \quad (20)$$
$$= U_t^i\left(s_t^n,u_t^n,z_t^n\right)+\beta\Omega_t^i\left(s_t^n\right)+\beta E_{u,z}V_{t+1}^i\left(s_{t+1}^n,u_{t+1}^n,z_{t+1}^n\right),$$

for all periods except T, and

$$V_T^i\left(s_T^n,u_T^n,z_T^n\right)=U_T^i\left(s_T^n,u_T^n,z_T^n\right)$$

for the last period, where β is the discount factor. Thus I can write the option value of moving as

$$\Omega_t^i\left(s_t^n\right)=E_{u,z}\left(\max_j\left\{V_{t+1}^j\left(s_{t+1}^n,u_{t+1}^n,z_{t+1}^n\right)-V_{t+1}^i\left(s_{t+1}^n,u_{t+1}^n,z_{t+1}^n\right)-C^{i,j}\left(s_t^n\right)\right\}|s_t^n\right), \quad (21)$$

and can be calculated numerically. For further discussion refer to the appendix.

Timing:

At any given time period t the order of events for a worker is as follows: 1. Pays the moving cost $C>0$ if her previous sector is different. 2. Works and enjoys her utility: $w_t^{ni}+v^i+u_t^{ni}$, 3. Learns the next period's random shocks $\left\{z_{t+1}^{nj},u_{t+1}^{nj}\right\}_{j=1}^{6}$. 4. Chooses her sector. 5. Enters the next period $t+1$ and repeats steps 1-5 for $t+1$.

Estimation Results - Model 2.1 from Artuc (2006a)

See tables A.1, A.2 and A.3 for basic model estimates. The estimated non-pecuniary moving cost C is quite large and statistically significant, approximately equal to 2.5 when a worker first enters the job market and increasing significantly by 0.095 every year. Note that the moving cost is very large because it captures all psychological moving costs and all unmodelled frictions. Keane and Wolpin (1994) and Lee and Wolpin (2004) report lower moving costs, however they do not consider idiosyncratic preference shocks for sectors (or occupations). Note that when idiosyncratic shocks are omitted, the moving costs are significantly lower as in the Model 2.5. However, such models do not fit the data well since fluctuations in the wages alone fail to explain the gross flows when preference shocks are ignored. Sullivan (2005) also reports high moving costs which cause significant reductions in the worker utility, as a results of the estimation of a labor mobility model with idiosyncratic preference shocks.

Another factor limiting worker mobility is the sectoral experience wage premium, (ϕ_4), which increases by 0.03 annually. Since the additional moving cost is large, it shows that much of the cost is psychological (non-pecuniary) and also quite variable, since the variance of idiosyncratic shocks is large. In other words, non-pecuniary factors also play an important role in the workers' mobility decisions .

High school graduates (ϕ_2) earn more than middle school graduates and less than college graduates (ϕ_3). The wage premium for market experience (ϕ_5) is about half the size of the

Table A.1: Basic Model (2.1) - Moving Cost Estimates

	C_0	C_1	C_0/σ_e
Estimate	2.536	0.095	1.805
Standard Error	(0.187)	(0.016)	(0.052)

Table A.2: Basic Model (2.1) - Wage Equation Estimates

	σ_z^2	ϕ_1	ϕ_2	ϕ_3	ϕ_4	ϕ_5
	Var(z_t)	Constant	HighSch	College	SecExp	MktExp
Estimate	0.160	0.164	0.215	0.478	0.034	0.020
Standard Error	(0.001)	(0.015)	(0.010)	(0.011)	(0.001)	(0.001)

wage premium for sector specific experience (ϕ_4). The fixed utility associated with each sector leads to the following ranking: most popular is Trade (υ^5), then Agriculture, Mining and Construction (υ^1), Service (υ^4), Manufacturing (υ^2), and the least popular is Metal (υ^3).

Calibration Parameters

Utility Function

We calibrate the utility function parameters from the "Relative importance of components in the Consumer Price Indexes: U.S. city average, December 2004" table. Since the utility function is Cobb-Douglas, share of sector i products can be considered as the parameter a_i. Note that products of whole/retail trade and metal manufacturing do not appear in this table. Processed foods enter in the manufacturing sector and fresh fruits; vegetables enter in the construction sector which also includes agriculture and mining. Consumers who rent, pay a different price for shelter compared to home owners: we consider the price paid by home owners because renting a house might include other services which should not be included as a part of construction sector but as a part of service sector (we add the difference to the service sector). Another important point is related to the main input of the construction sector which is land: since we do not consider land as an input we deduct the approximate cost of land from the cost of shelter. We assume that cost of land is approximately 60%, of course this number is a guess and it would be different for each city. The share of construction sector is approximately 10%, the share of manufacturing is approximately 40%, and the share of service sector is about 50% in our model.

Production Functions

The share of inputs for each product can be considered as parameters of the Cobb-Douglas

Table A.3: Basic Model (2.1) Utility Estimates

	υ^1	υ^2	υ^3	υ^4	υ^5	υ^6
	Construc.	Manuf.	Metal.	Service	Trade	Home
Estimate	0.508	0.434	0.262	0.471	0.574	0
Standard Error	(0.090)	(0.093)	(0.080)	(0.097)	(0.091)	-

production function, b^i_j. We mainly use the set of tables labeled as "The Use of Commodities by Industries after Redefinitions, 1997" from the Bureau of Economic Analysis' internet site. We consider the output levels before tax. We use a one digit industry table for all sectors except Manufacturing and Metal. For sectors which are consist of more than one sector, such as service, we take a weighted average of shares. For manufacturing and metal sectors we use a four digit table, we combine sub-divisions of metal industry and subtract them from the manufacturing shares from the one digit table and take the relative size of metal sector into account. The results are summarized in table 3.1.

Before calibrating the coefficient B^i, we normalize all inputs $x^{i,j}_t = 1$, for every i, j, t and we normalize total labor $\sum_n \sum_j L^{nj} = 1$ where n stands for the worker type. The average sectoral experience of workers is endogenous in the model; we use probabilities of sector change to calculate average sectoral experience. Using the average sectoral experience and education levels for each sector we calculate average human capital level for each sector, which then, is used to calculate effective total labor in each sector, $L^i_t \bar{h}^i_t$. Then we pick B^i such that, average real wage in each sector is equal to implied average real wage over the years:

$$\sum_{t=1}^{17} w^i_t = B^i b^i_6 \left(L^i_t \bar{h}^i_t\right)^{b^i_6 - 1},$$

note that we do not need to worry about the inputs since they are normalized to one. After this calibration, we need to consider quantities of inputs relative to the autarky quantities, $x^{i,j}_t / x^{i,j}_{Autarky}$ to use them in the production function.

Labor Supply

The parameters, C_0, C_1, C_0/σ_e, ϕ_4, ϕ_5, ϕ^i_6, υ^1, υ^2,..., υ^6 are taken from the estimates of Model 2.1. The parameter, ϕ^i_6, is a weighted average of ϕ_1, ϕ_2, ϕ_3 given the percentage of high school and college graduates for each sector.

Solution Method for Simulations

We use a method similar to multiple shooting, described in Lipton et al. 1982, to solve for the transition and steady states. The solution described here is for one type of worker, it can be generalized for more than one type simply by increasing the state space.

Autarky Steady State:

In autarky prices are given as 1 for all sectors and the inputs $x^{i,j}$ are also normalized to unity. Therefore we solve the system without worrying about the prices ad inputs since all parameters are calibrated under the assumption of all prices being unity.

We will exploit the lack of aggregate uncertainty, the only uncertainty is the one time shock to price because of trade liberalization. So the system we are solving is deterministic since we only have a one time shock and nothing else stochastic. The random idiosyncratic shocks in the model do not make the aggregate system stochastic because we have a continuum of workers, hence all agents have a perfect foresight of the aggregate parameters (except the trade shock). If we know the steady state labor allocation, L^i, we can calculate wages, w^i. If we know the steady state values of workers, V^i, we can calculate their probabilities of sector change, m^{ij}. Moreover knowing m^{ij} and w^i it is possible to calculate values of workers V^i. Hence all parameters can be considered functions of other parameters:

$$w_t^i = \frac{p_t^i}{CPI_t} \frac{\partial q^i \left(L_t^i\right)}{\partial L_t^i},$$

where q^i is the production function and CPI_t is the consumer price index. Probability of sector change

$$m_t^{nik} = E_z \frac{\exp\left[\left(E_u V_{t+1}^{nk} - E_u V_{t+1}^{ni} - C^{n,i,k}\right)/\nu\right]}{\sum_j \exp\left[\left(E_u V_{t+1}^{nj} - E_u V_{t+1}^{ni} - C^{n,i,j}\right)/\nu\right]}$$

Value of workers

$$E_u V_t^i = w_t^i + \upsilon^i + \nu \log\left(1 + \exp\left(m_t^{ii}/\nu\right)\right) + \beta E V_{t+1}^i,$$

Labor allocation

$$L_{t+1}^{nj} = \sum_{r=1}^{10} \tilde{P}\left(s_{t+1}^n | s_t^r\right) \sum_{i=1}^{6} L_t^{ri} m_t^{rij}$$

Let

$$X_t = \left[L_t^1, L_t^2 ..., L_t^{60}, V_t^1, V_t^2, ..., V_t^{60}\right]',$$

and consider the system above as a mapping $F : \Re^{120} \rightarrow \Re^{120}$, such that $X_t = F\left(X_{t+1}\right)$. In the steady state $X_t = X_{t+1}$, therefore there is a fixed point of function F. The steady state is the solution of the nonlinear equation

$$F\left(X^{SS}\right) - X^{SS} = 0.$$

which can be solved by any nonlinear equation solver.

Free Trade Steady State:

For the free trade steady state we have to worry about the prices because prices are actually endogenous for some sectors and a drop in the metal sector price will effect prices endogenously, deviating from the autarky price levels in many sectors.

Assume that the autarky output levels are given as q_A^i, for $i = 1..I$. For the traded goods the prices will still be exogenous and equal to world price, $p_{FT}^i = p_W^i$, however the free trade outputs for all sectors and the prices for non-traded sectors will be endogenous to the model, p_{FT}^i and q_{FT}^i. The price levels will be determined by the equation

$$p_t^i = \frac{q_A^i}{q_t^i} \frac{a_i \sum_{j=1}^{I-1} \left(b_6^j + b_7^j\right) q_t^j p_t^j + \sum_{j=1}^{I-1} b_i^j q_t^j p_t^j}{a_i \sum_{j=1}^{I-1} \left(b_6^j + b_7^j\right) q_A^j + \sum_{j=1}^{I-1} b_i^j q_A^j},$$

and the quantities will be determined by

$$q_t^i = B^i \left(L_t^i \bar{h}_t^i\right)^{b_6^i} \prod_{j=1}^{I-1} \left(\frac{1}{p_t^j} \frac{q_t^i p_t^i}{q_A^i}\right)^{b_j^i},$$

where $t = FT$. Therefore q_{FT}^i's and p_{FT}^i's are included as control variables in the system, but the solution method is almost identical to the autarky solution except whys time we have two more equations. Let

$$X_t = \left[L_t^1, L_t^2 ..., L_t^{60}, V_t^1, V_t^2, ..., V_t^{60}, q_t^1, q_t^2, ..., q_t^5, p_t^1, p_t^2, ..., p_t^5\right]',$$

and consider the system above as a mapping $F : \Re^{130} \rightarrow \Re^{130}$, such that $X_t = F(X_{t+1})$. In the steady state $X_t = X_{t+1}$, therefore there is a fixed point of function F. The steady state is the solution of the nonlinear equation

$$F\left(X^{SS}\right) - X^{SS} = 0.$$

which can be solved by any nonlinear equation solver.

Transition:

Solving for transition is relatively more difficult than the steady state but the problem can be attacked by a similar approach. The economy is at autarchy steady state equilibrium initially, at time 0 and then the economy switches to free trade as shock therapy. Consider the system above, assume starting from $t = 0$ the economy will become sufficiently close to its free trade steady state X^{FT} at $t = T$, such that $\left(X_T - X^{FT}\right)'\left(X_T - X^{FT}\right) < \delta$,where δ is a very small number for the tolerance level. We will conveniently assume that $X_{T+k} = X_T$ for every $k \geq 0$, since there will not be any aggregate shocks in the economy. Let $X = [X_0, X_1, X_2, ..., X_T]'$, be the transition of all state and control variables starting from $t = 0$, (autarchy) until $t = T$, (free trade steady state). Then we can define a mapping from $H : \Re^{70(T+1)} \times [0,1]^{60} \rightarrow \Re^{70(T+1)}$, such that $X = H(X, L_0)$. Therefore this problem is just a larger version of the steady state problem. We solve the nonlinear equation

$$H(X, L_0) - X = 0, \tag{22}$$

to find the fixed point. Note that this time we can consider

$$X_t = \left[V_t^1, V_t^2, ..., V_t^{60}, q_t^1, q_t^2, ..., q_t^5, p_t^1, p_t^2, ..., p_t^5\right]',$$

since the initial labor allocation, L_0, is now known and it can be calculated forward.

In practice we first find the steady state of autarchy and of free trade. Then we guess a value for T, such as 40. Starting from the steady state autarchy labor allocation we solve the nonlinear equation (22).Finally we check if X_T is equal to the free trade steady state, if so we are done and if not we increase T, and repeat the procedure.

Notes on Wage Equation

Consider the production function:

$$y = b\left(\sum_n L^n h^n\right)^{\alpha},$$

where b is a constant which accounts for the production function coefficient and all non-labor inputs and L^n is the number of workers with effective human capital level h^n. Assume that workers receive their real marginal product:

$$w^n = \frac{p}{\phi}\frac{\partial y}{\partial L^n},$$

where p is the price of the product and ϕ is the price index. Then

$$w^n = \frac{p}{\phi}b\alpha\left(\sum_n L^n h^n\right)^{\alpha-1} h^n,$$

where L is the total number of workers. Assume that $\bar{h}$. is the average human capital in sector. Now consider the human capital accumulation process: $h^n = H(s^n) + z$, then the average effective human capital in the sector is $\bar{h} = \frac{1}{L}\left(\sum_n L^n h^n\right)$,where H is a *linear* function of state variables s^n and z is a mean random shock to each worker's effective human capital. Note that z is different for all workers and it is mean zero. Therefore we can write wages using average human capital such as

$$w^n = \frac{p}{\phi}b\alpha\left(L\bar{h}\right)^{\alpha-1} h^n,$$

Now consider the average wage in sector:

$$\bar{w} = \frac{p}{\phi}b\alpha\left(L\bar{h}\right)^{\alpha-1} \bar{h}.$$

Hence we can write wages as a function of average effective human capital and average wages in sectors

$$\begin{aligned} w^n &= \frac{p}{\phi}b\alpha\left(L\bar{h}\right)^{\alpha-1} h^n, \\ &= \bar{w}\frac{h^n}{\bar{h}}. \end{aligned}$$

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Figure 1.1: Labor Flows Out of Construction Sector

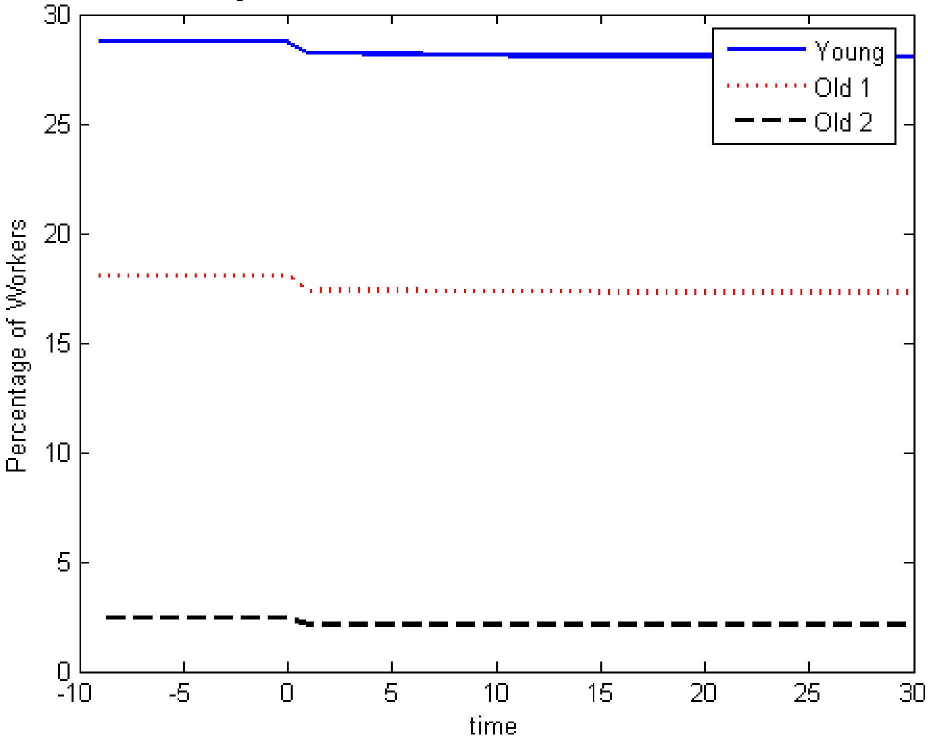


Figure 1.2: Labor Flows Out of Manufacturing Sector

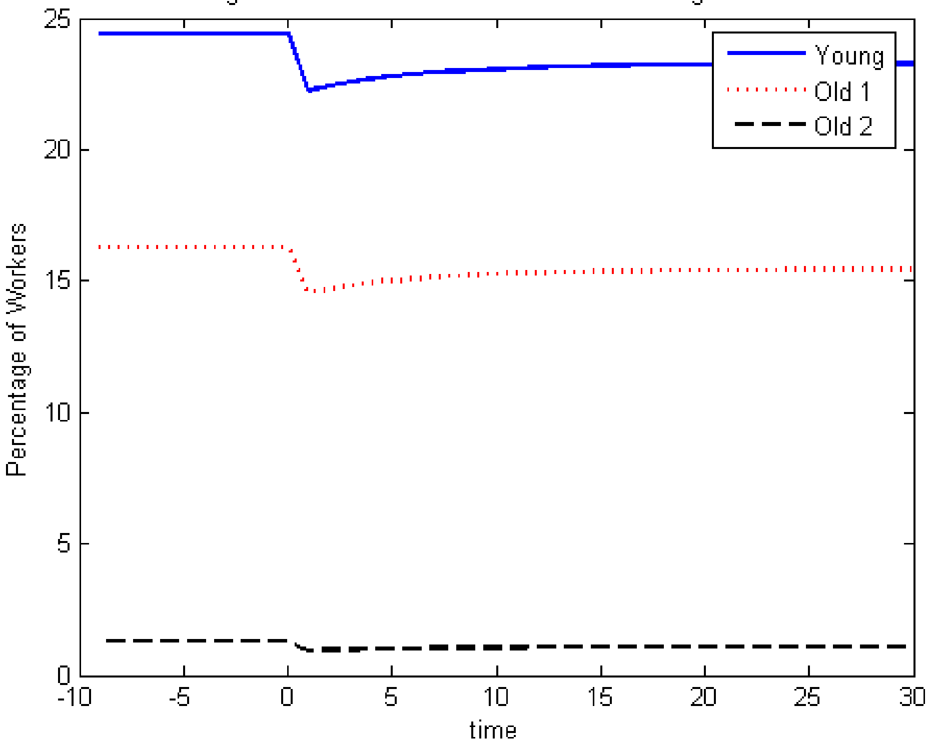


Figure 1.3: Labor Flows Out of Metal Sector

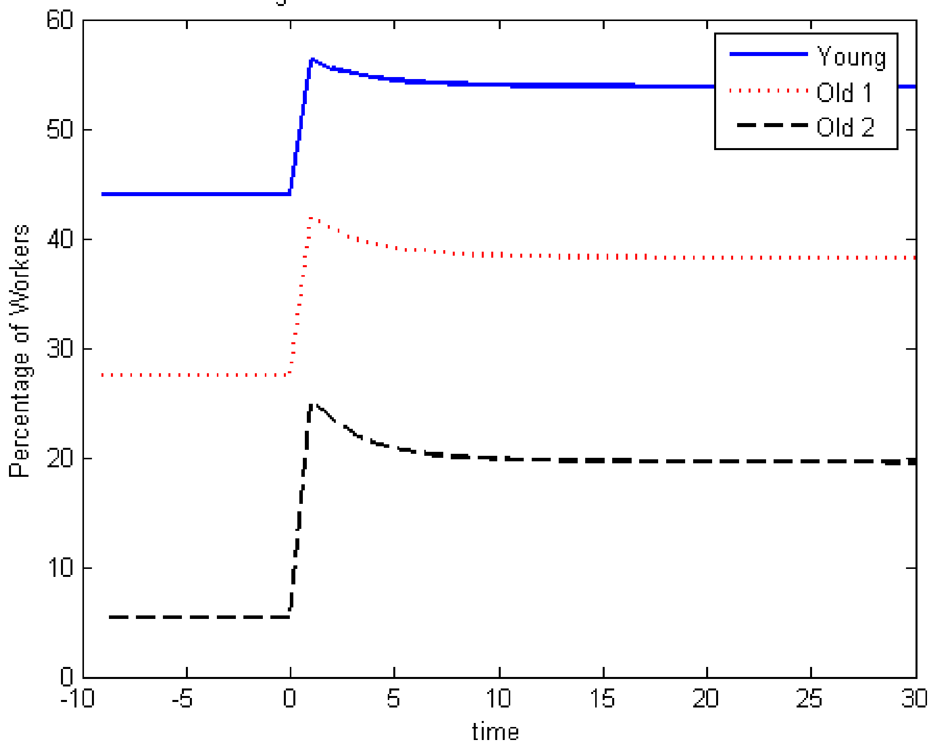
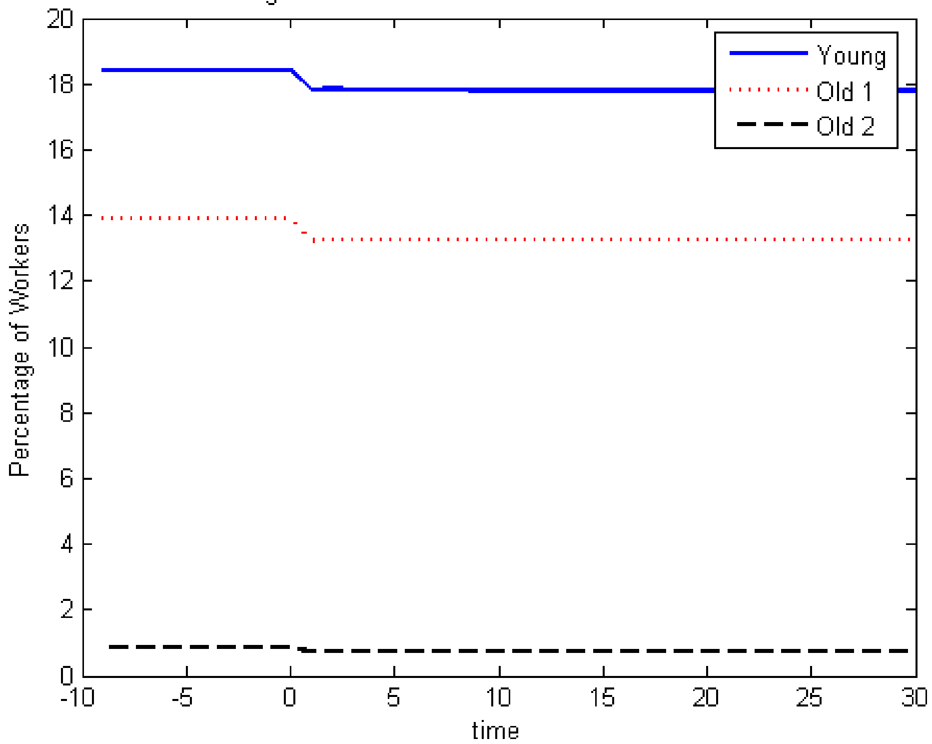


Figure 1.4: Labor Flows Out of Service Sector



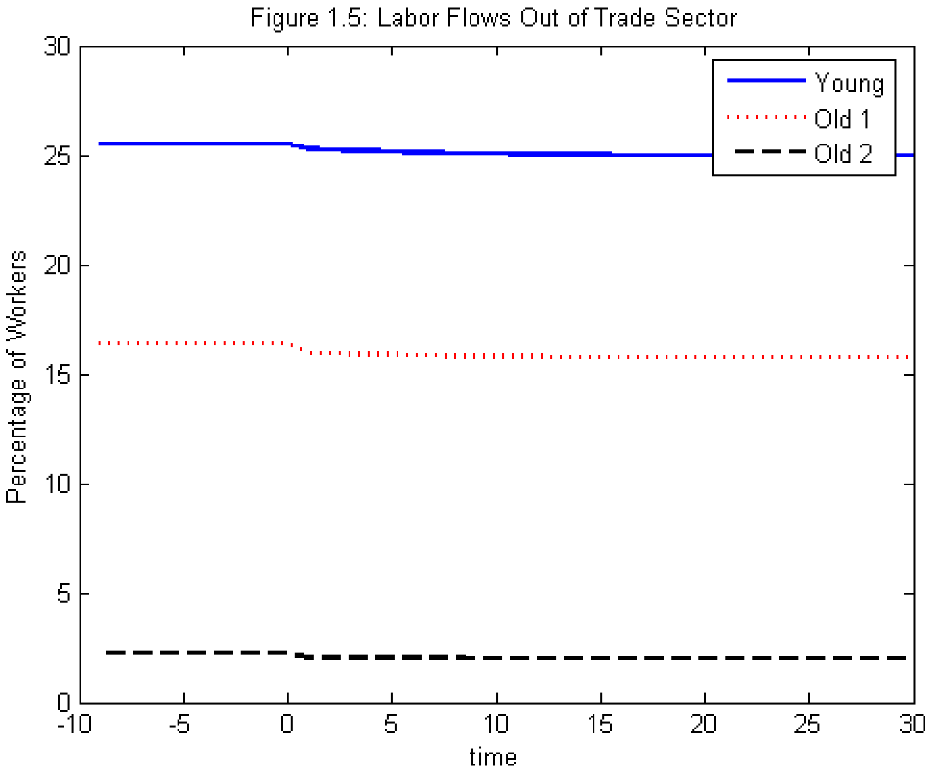


Figure 1.5: Labor Flows Out of Trade Sector
Young
Old 1
Old 2
Percentage of Workers
time
30
25
20
15
10
5
0
-10
-5
0
5
10
15
20
25
30

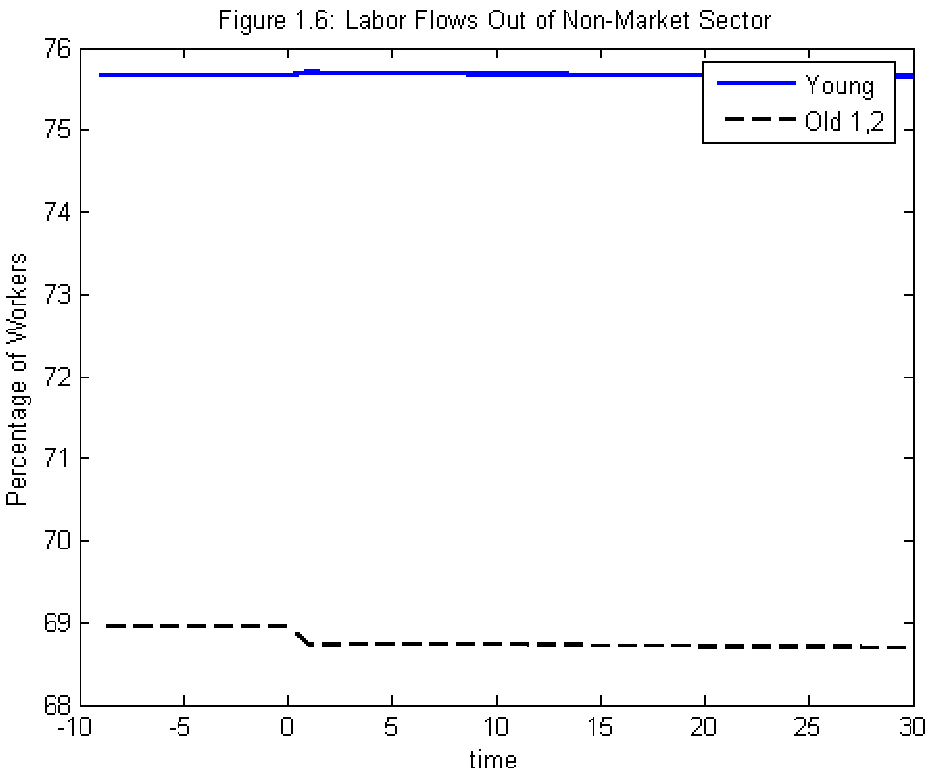


Figure 1.6: Labor Flows Out of Non-Market Sector
Young
Old 1,2
Percentage of Workers
time
76
75
74
73
72
71
70
69
68
-10
-5
0
5
10
15
20
25
30

Figure 2.1: Labor Adjustment in Construction Sector

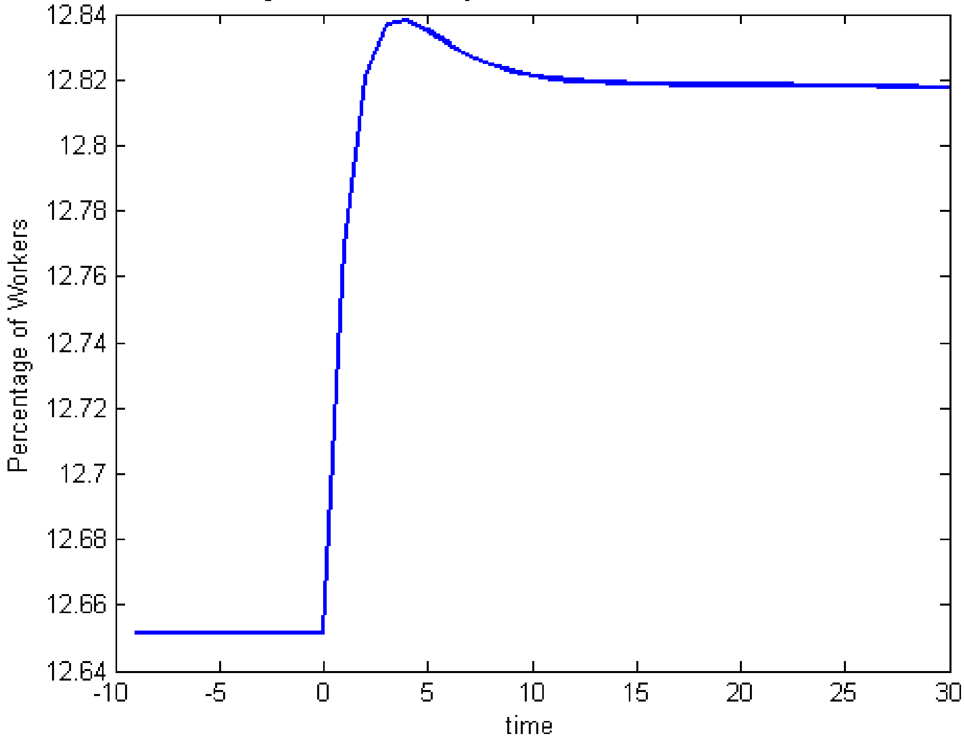
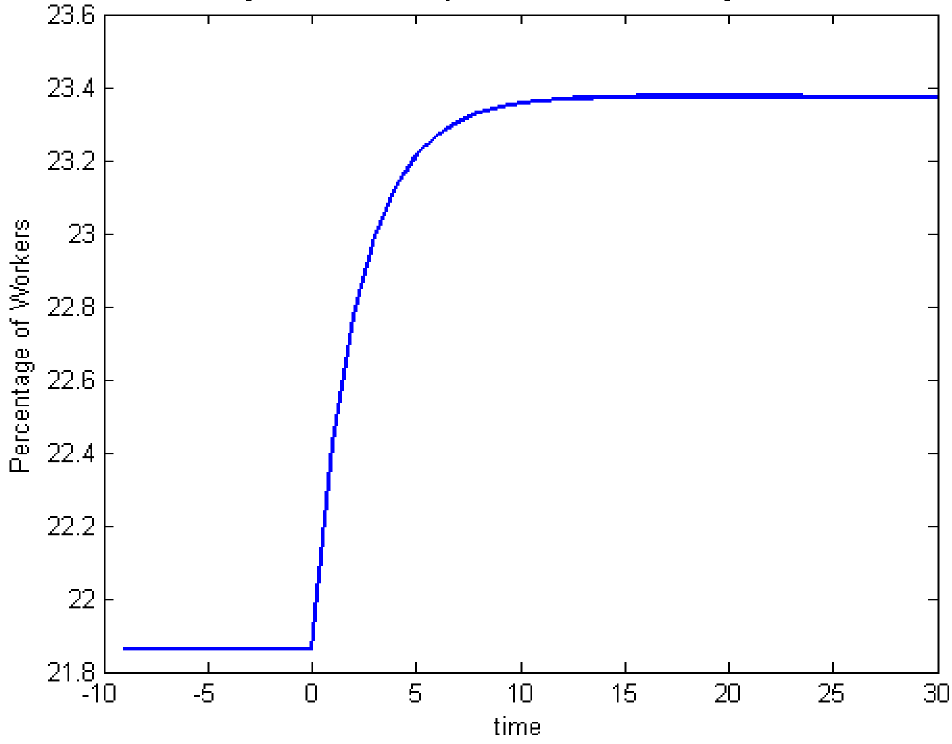


Figure 2.2: Labor Adjustment in Manufacturing Sector



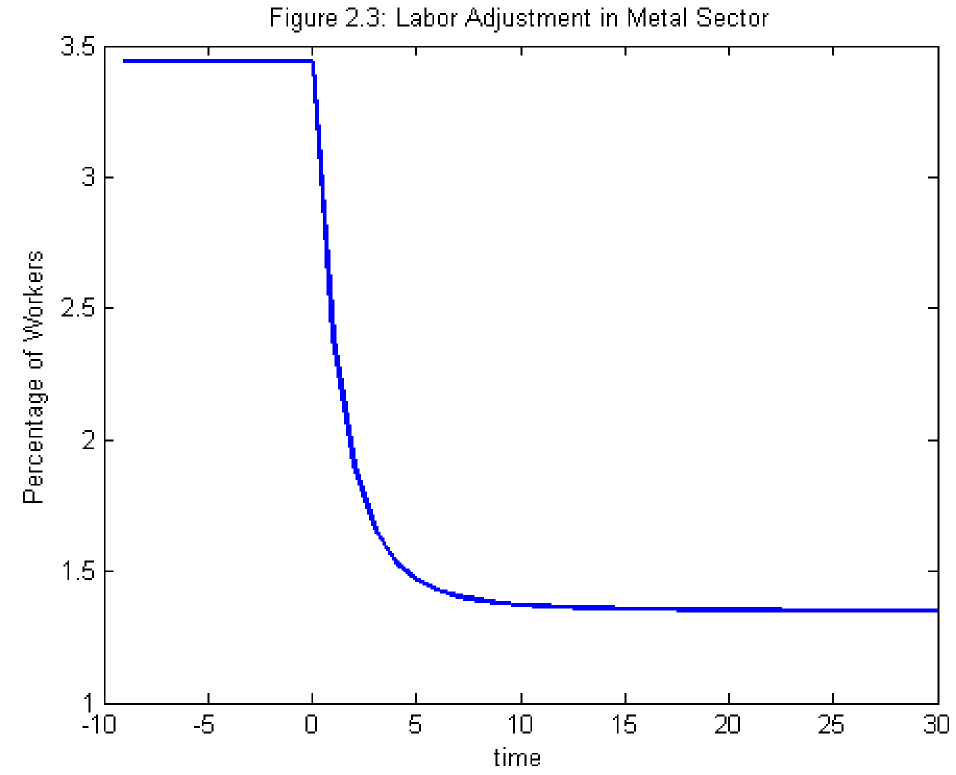


Figure 2.3: Labor Adjustment in Metal Sector
Percentage of Workers
time
3.5
3
2.5
2
1.5
1
-10
-5
0
5
10
15
20
25
30

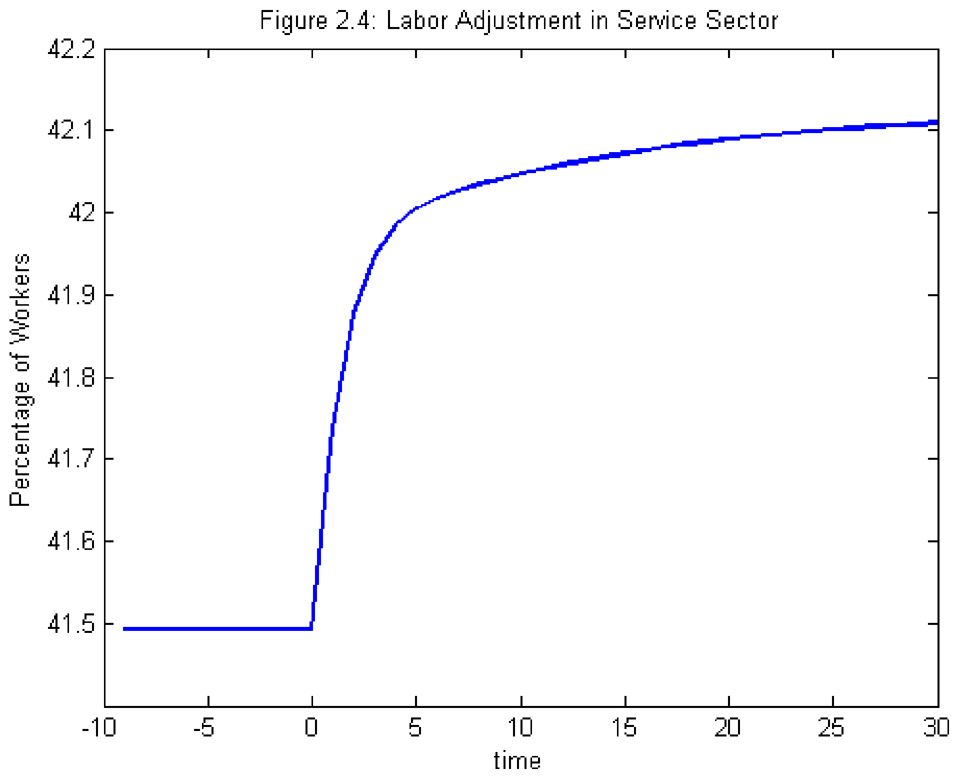


Figure 2.4: Labor Adjustment in Service Sector
Percentage of Workers
time
42.2
42.1
42
41.9
41.8
41.7
41.6
41.5
-10
-5
0
5
10
15
20
25
30

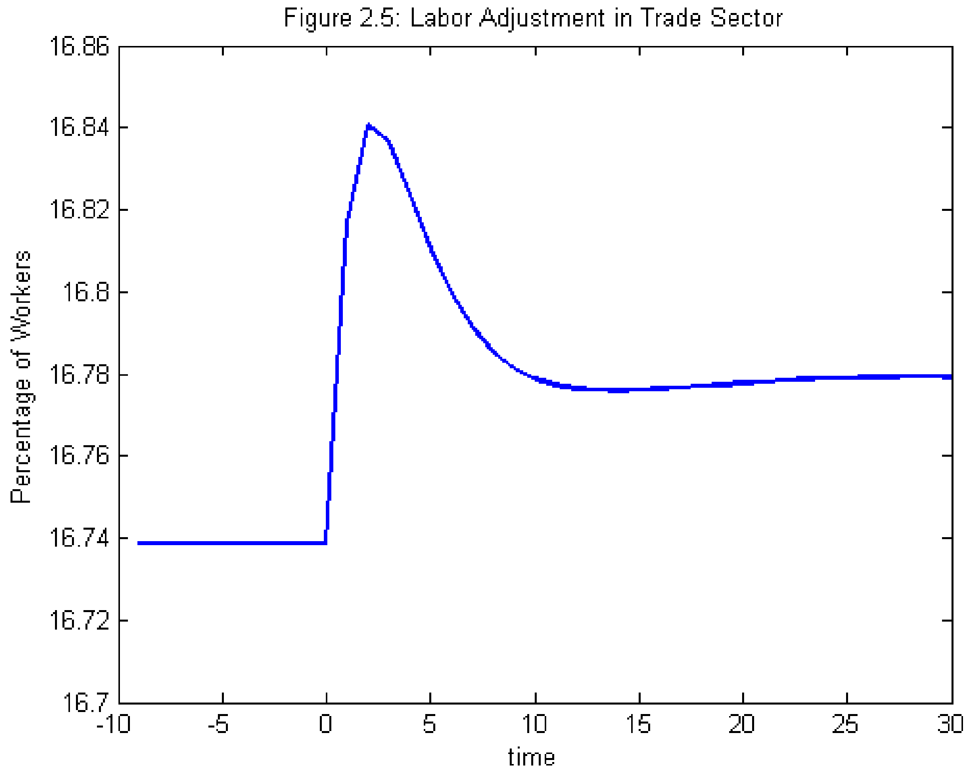


Figure 2.5: Labor Adjustment in Trade Sector
Percentage of Workers
16.86
16.84
16.82
16.8
16.78
16.76
16.74
16.72
16.7
-10
-5
0
5
10
15
20
25
30
time

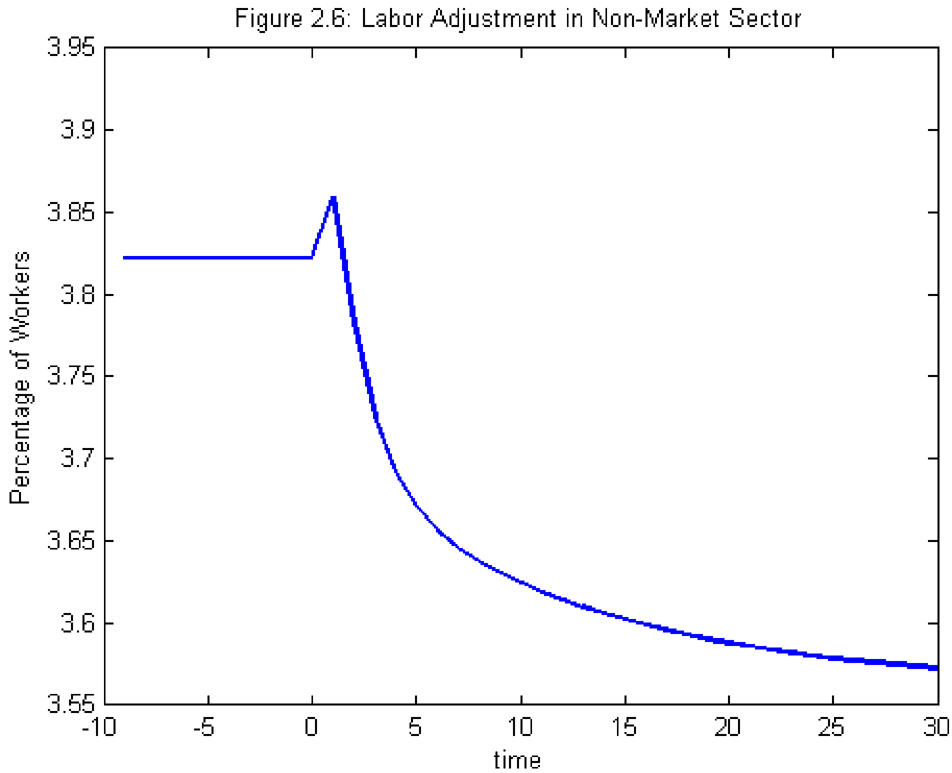


Figure 2.6: Labor Adjustment in Non-Market Sector
Percentage of Workers
3.95
3.9
3.85
3.8
3.75
3.7
3.65
3.6
3.55
-10
-5
0
5
10
15
20
25
30
time

Figure 3.1: Adjustment of Construction Sector Output

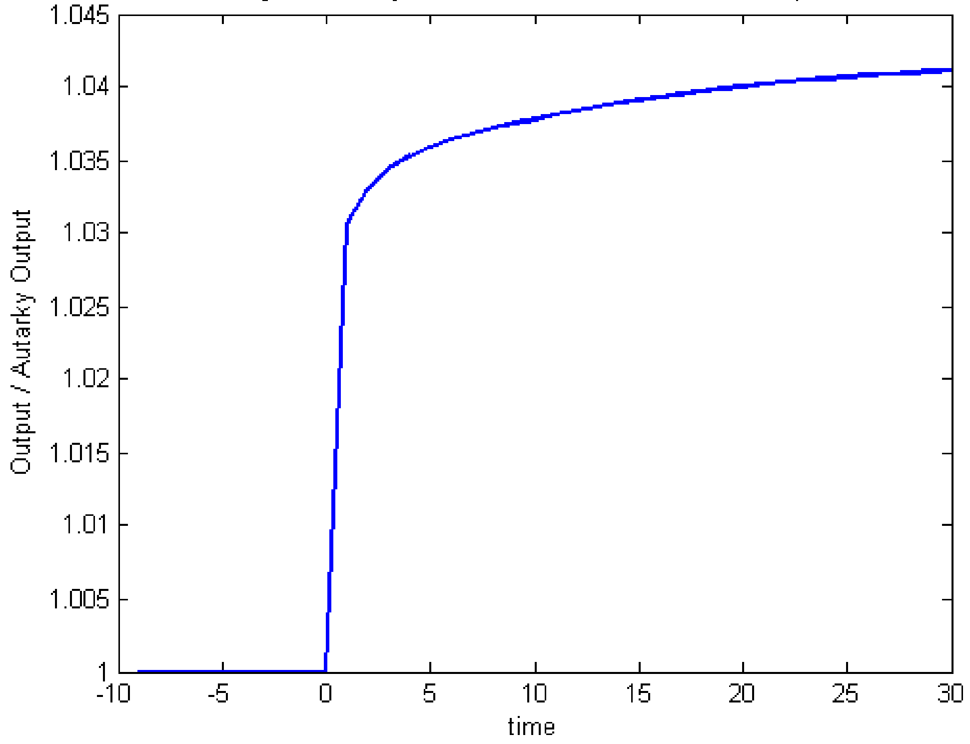


Figure 3.2: Adjustment of Manufacturing Sector Output

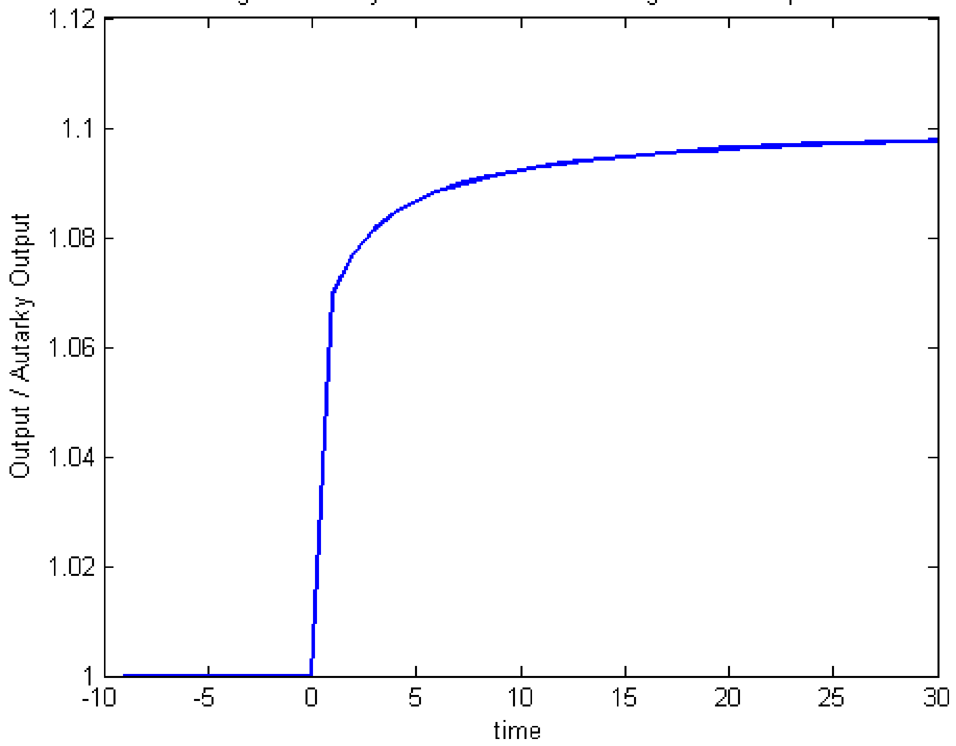


Figure 3.3: Adjustment of Metal Sector Output

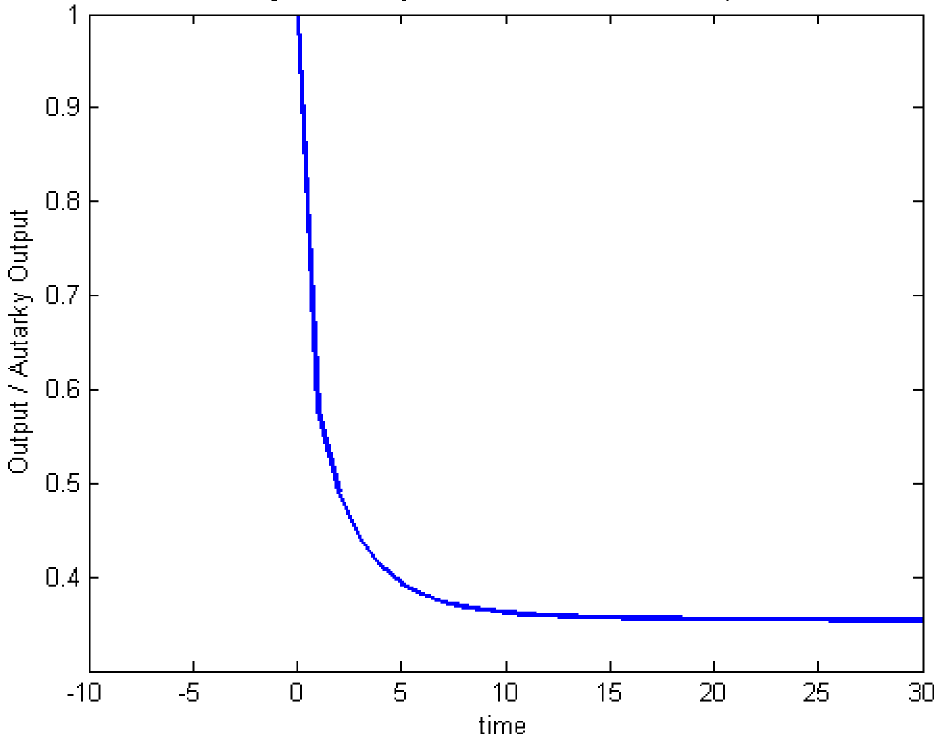


Figure 3.4: Adjustment of Service Sector Output

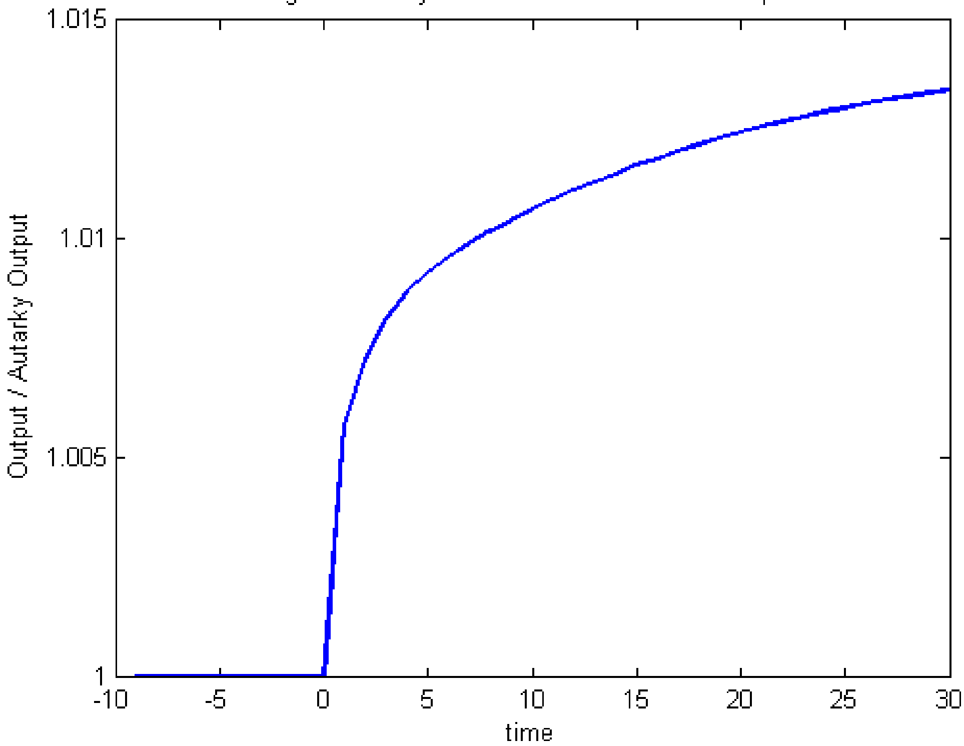


Figure 3.5: Adjustment of Trade Sector Output

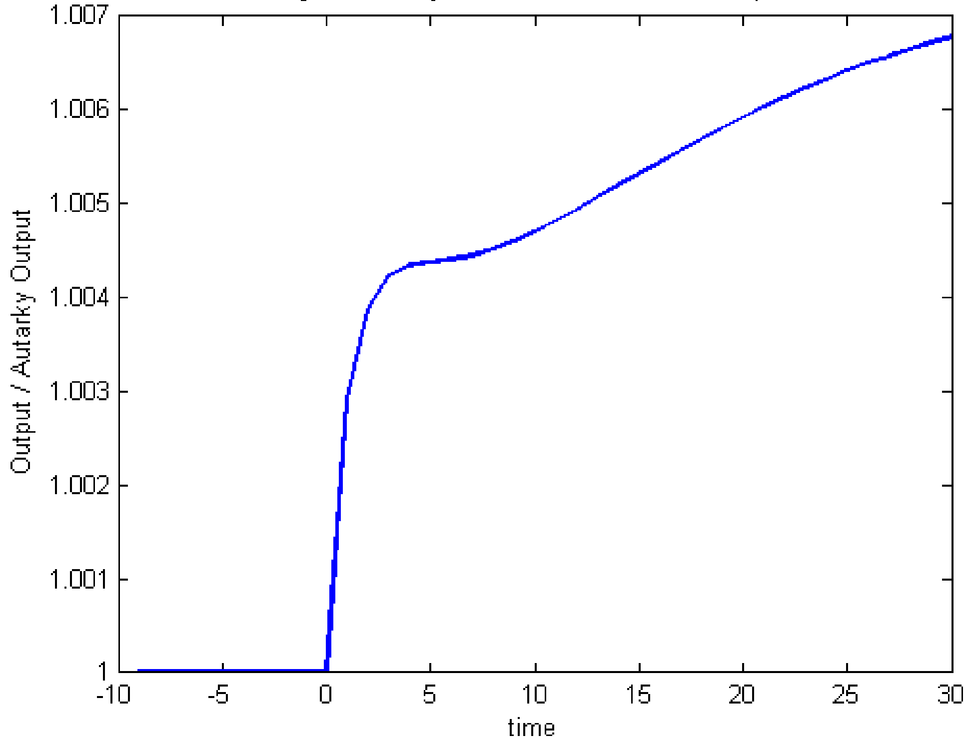


Figure 3.6: Adjustment of Total Output

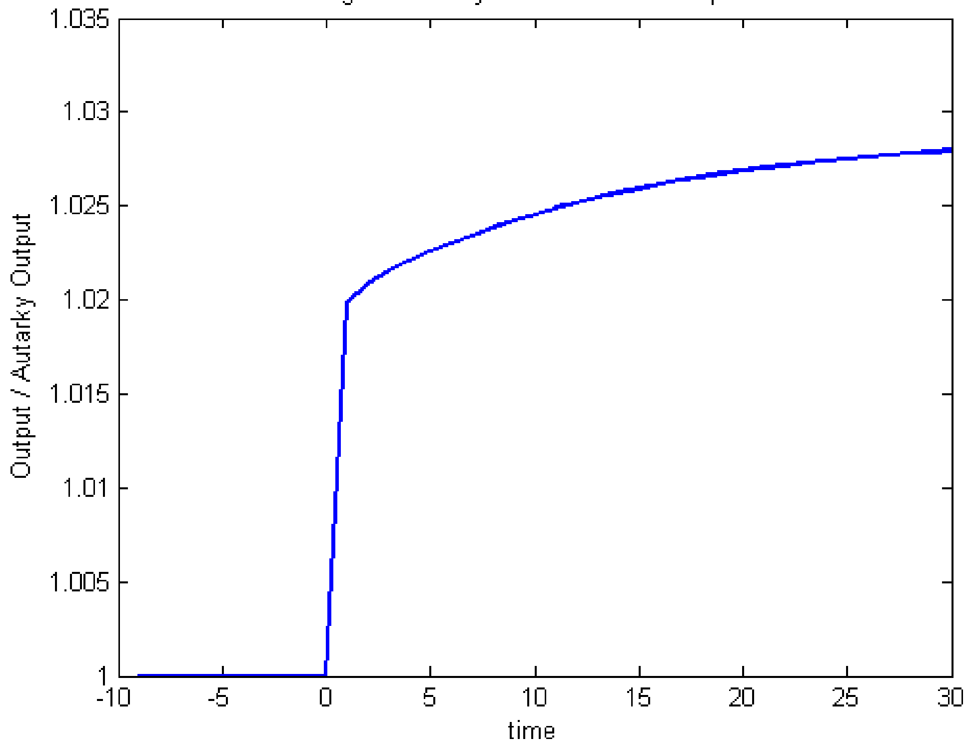


Figure 4.1: Price Adjustment of Construction Sector Product

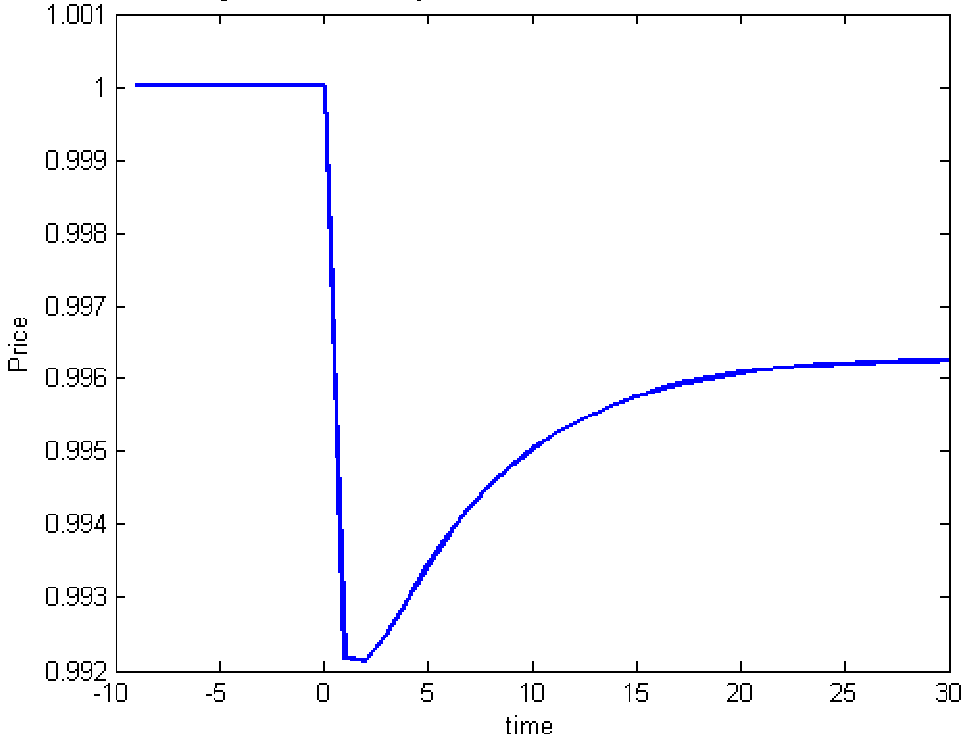


Figure 4.2: Price Adjustment of Manufacturing Sector Product

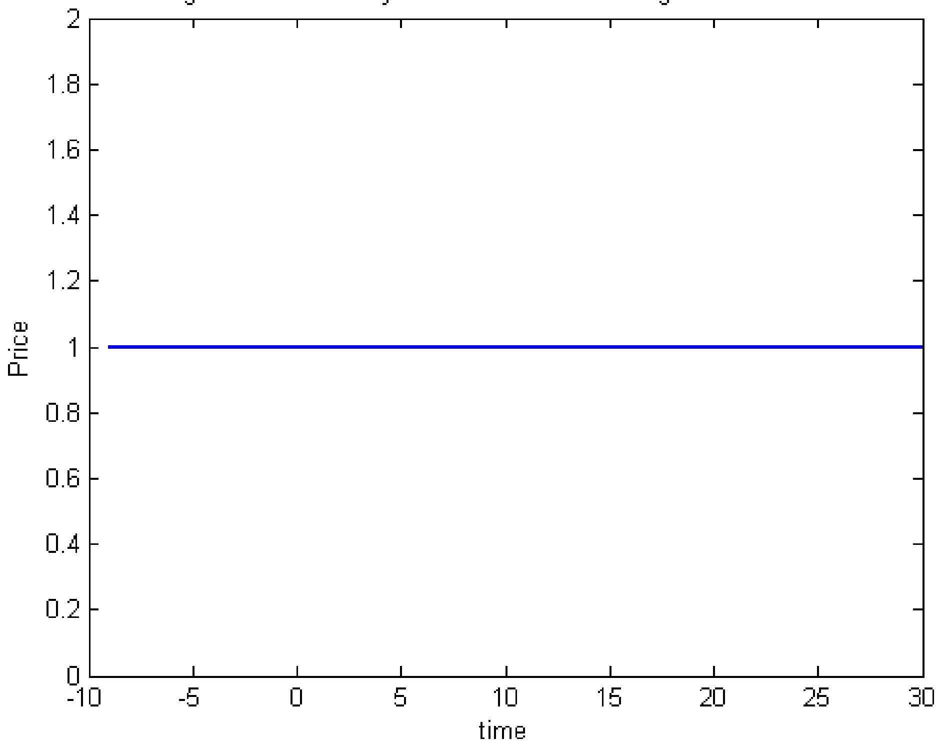


Figure 4.3: Price Adjustment of Metal Sector Product

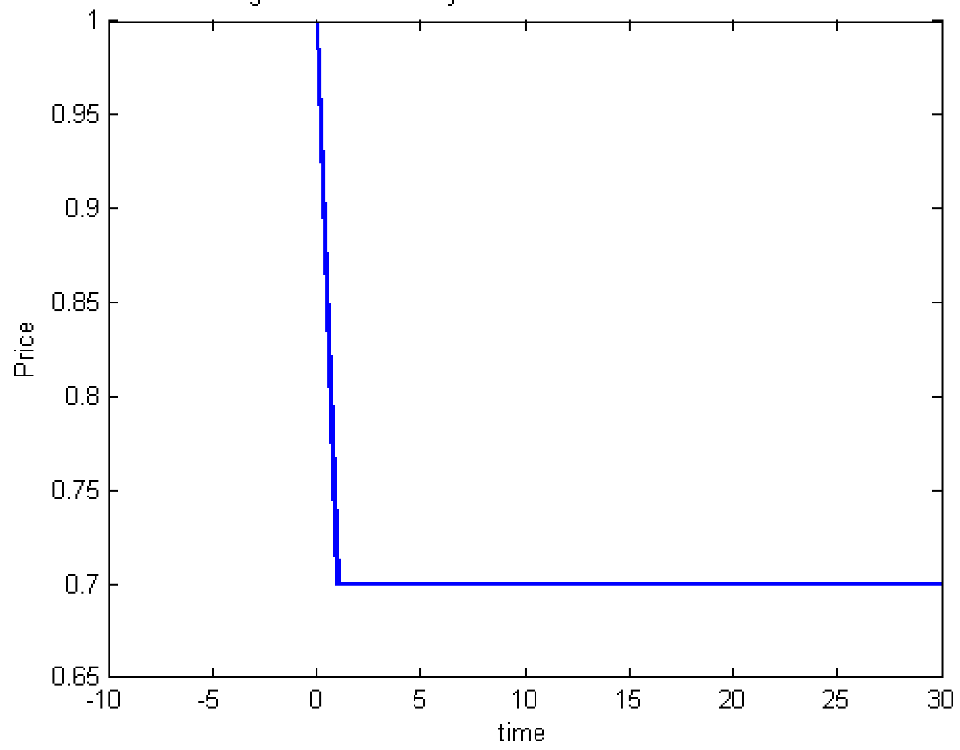


Figure 4.4: Price Adjustment of Service Sector Product

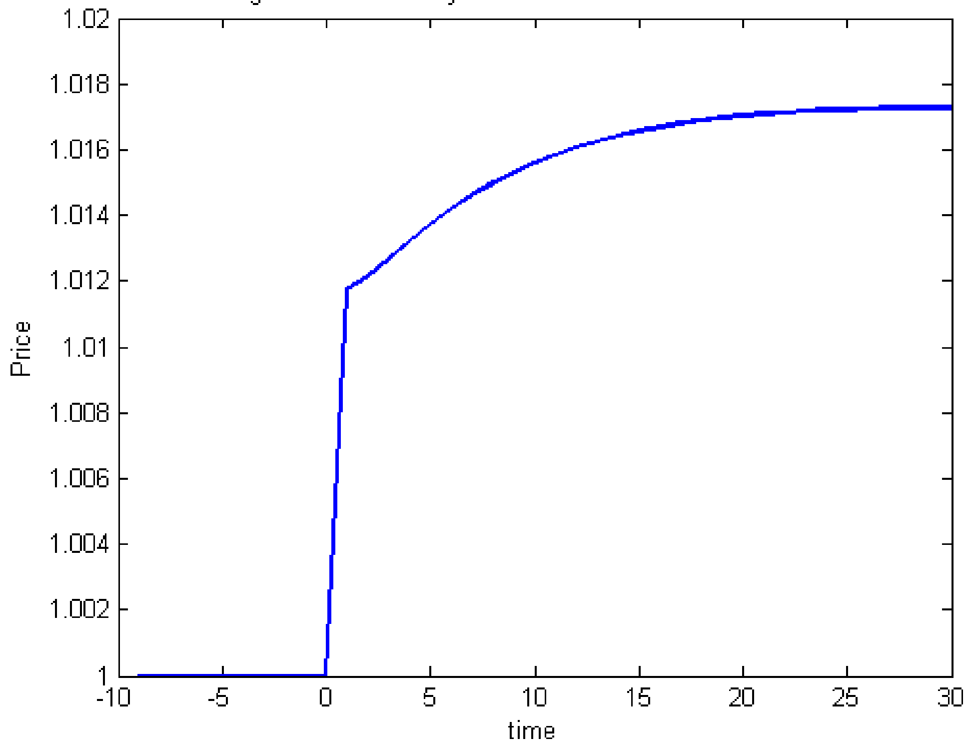


Figure 4.5: Price Adjustment of Trade Sector Product

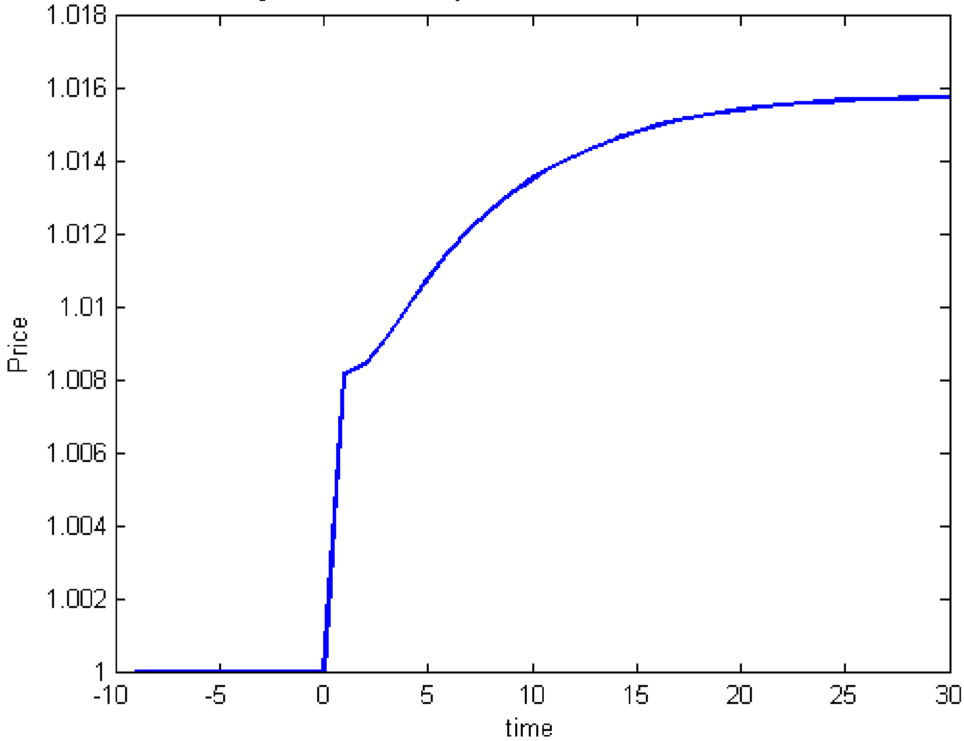


Figure 4.6: Adjustment of Consumer Price Index

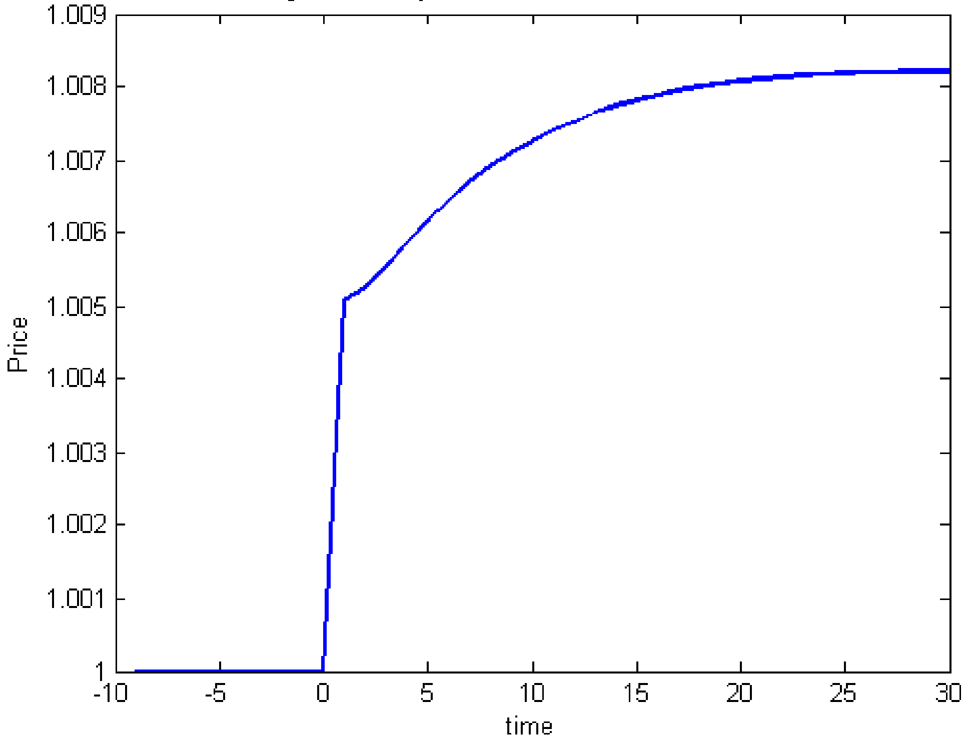


Figure 5.1: Wage Adjustment in Construction Sector

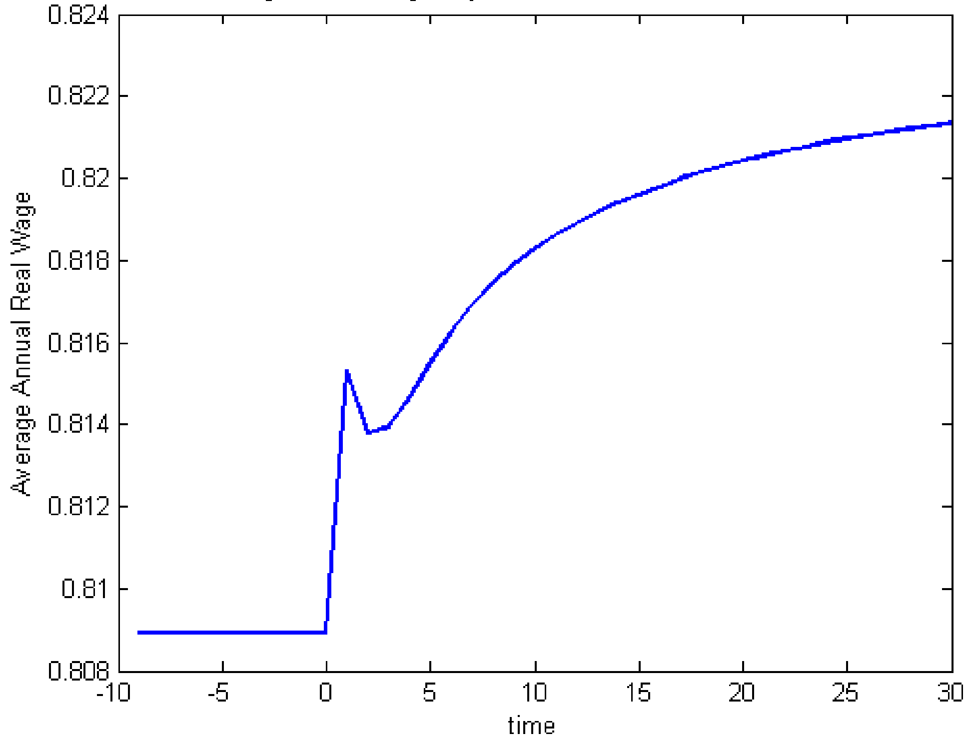


Figure 5.2: Wage Adjustment in Manufacturing Sector

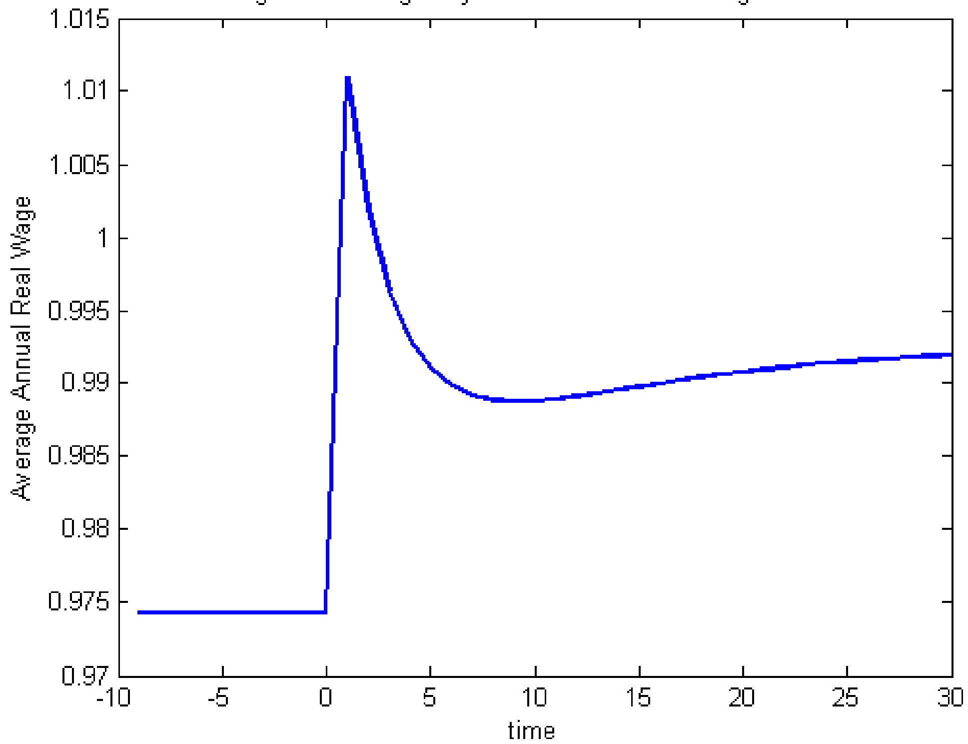


Figure 5.3: Wage Adjustment in Metal Sector

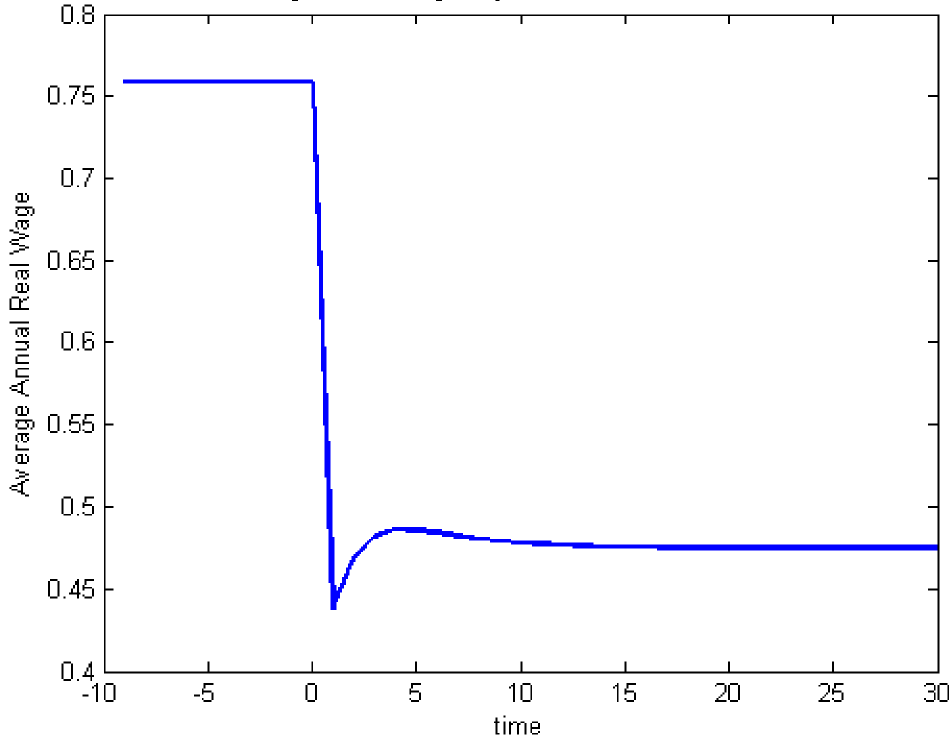


Figure 5.4: Wage Adjustment in Service Sector

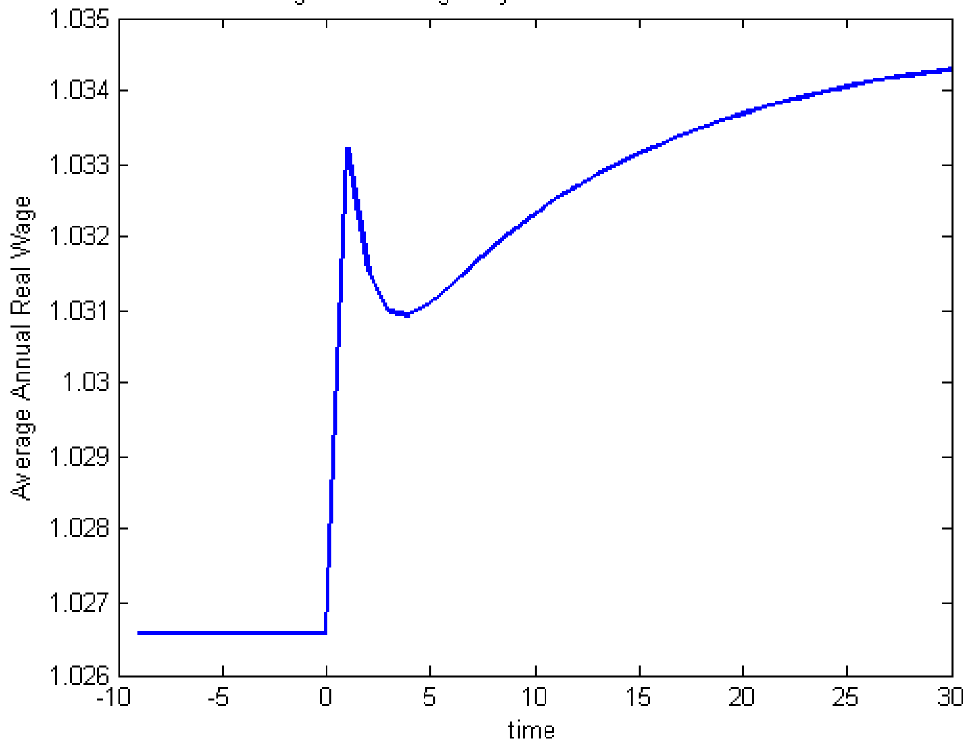


Figure 5.5: Wage Adjustment in Trade Sector

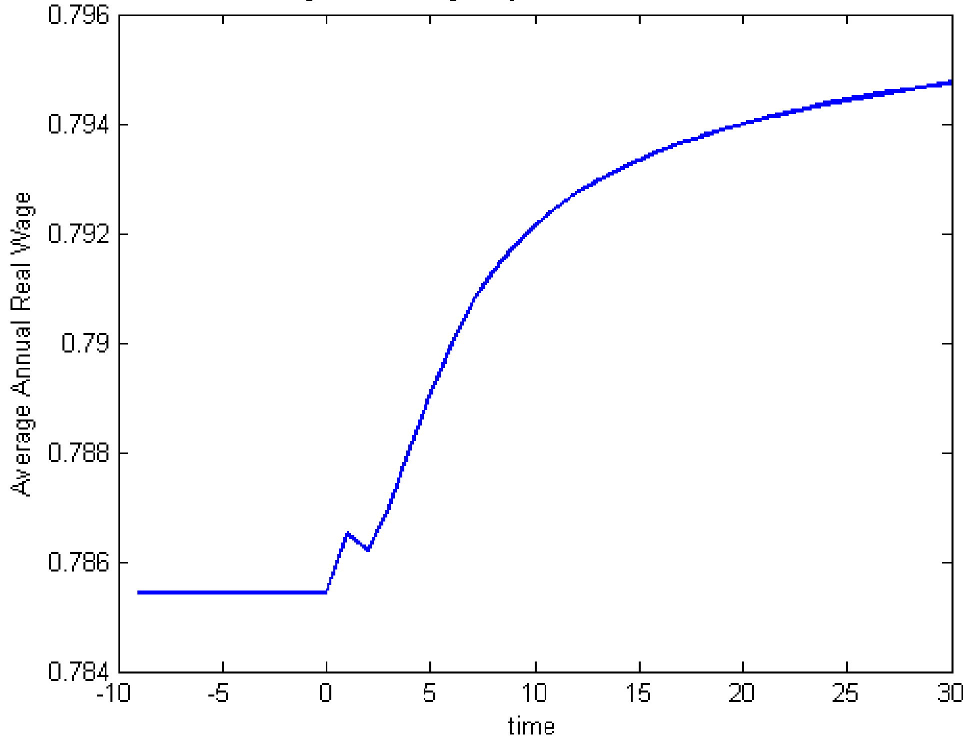


Figure 6.1: Change in Value of Construction Workers

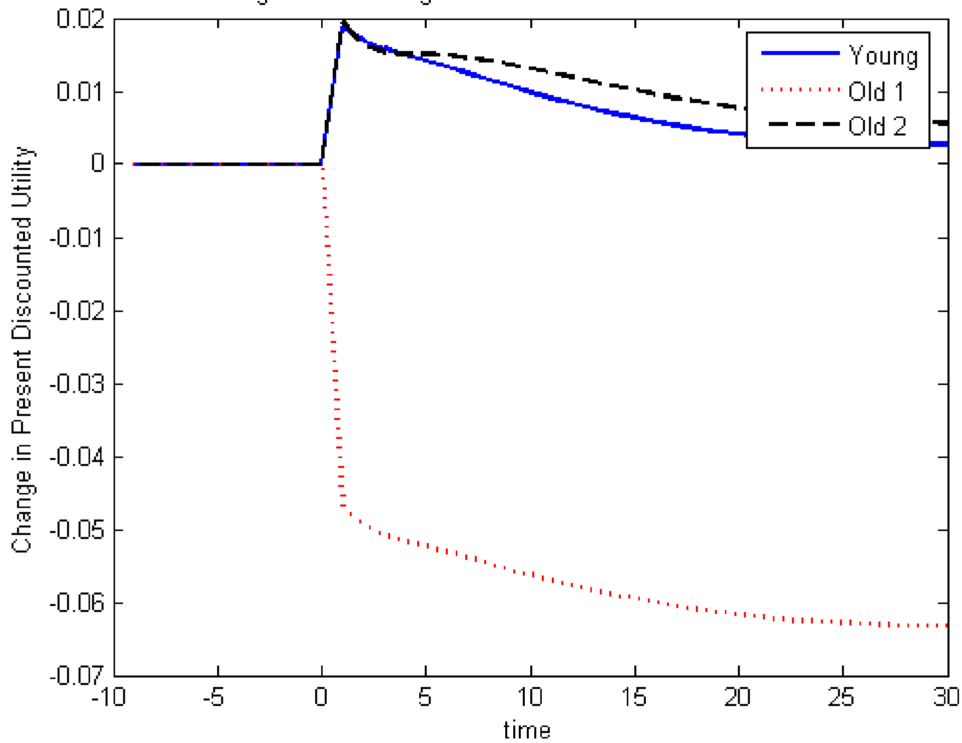


Figure 6.2: Change in Value of Manufacturing Workers

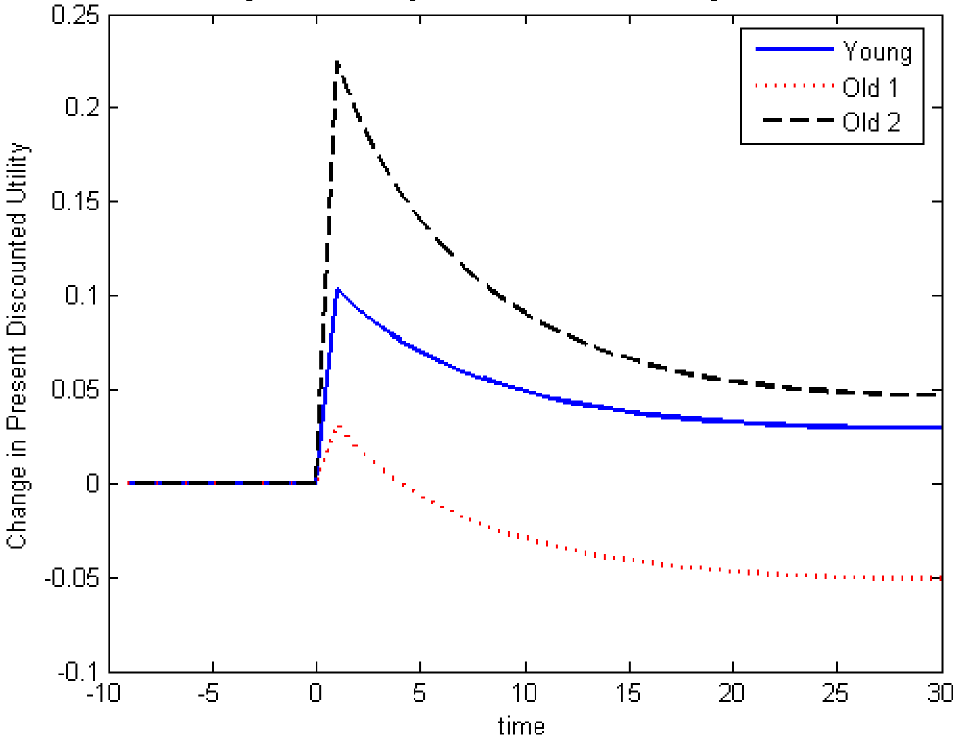
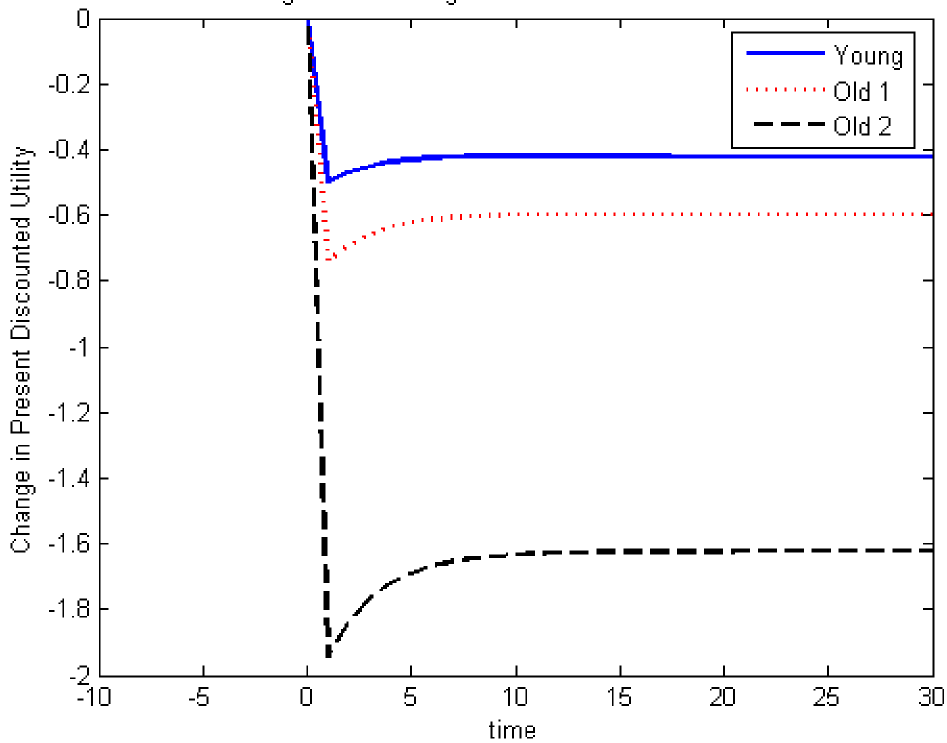


Figure 6.3: Change in Value of Metal Workers



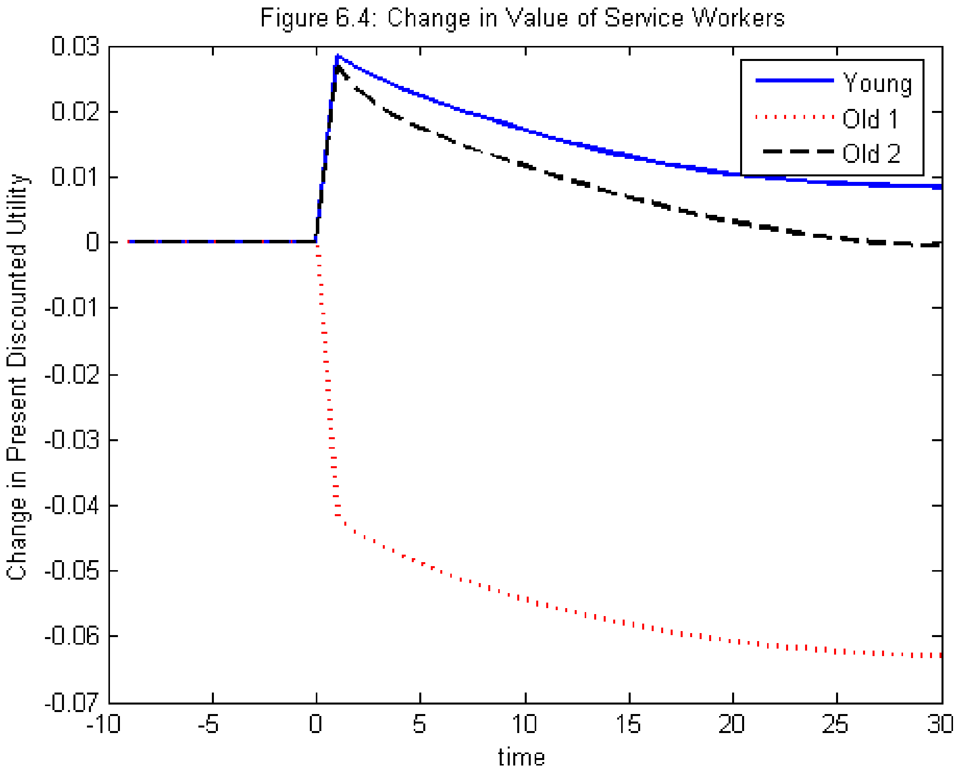


Figure 6.4: Change in Value of Service Workers
Change in Present Discounted Utility
time
Young
Old 1
Old 2
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-10
-5
0
5
10
15
20
25
30


Figure 6.5: Change in Value of Trade Workers
Change in Present Discounted Utility
time
Young
Old 1
Old 2
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-10
-5
0
5
10
15
20
25
30

Figure 6.6: Change in Value of Non-Market Workers

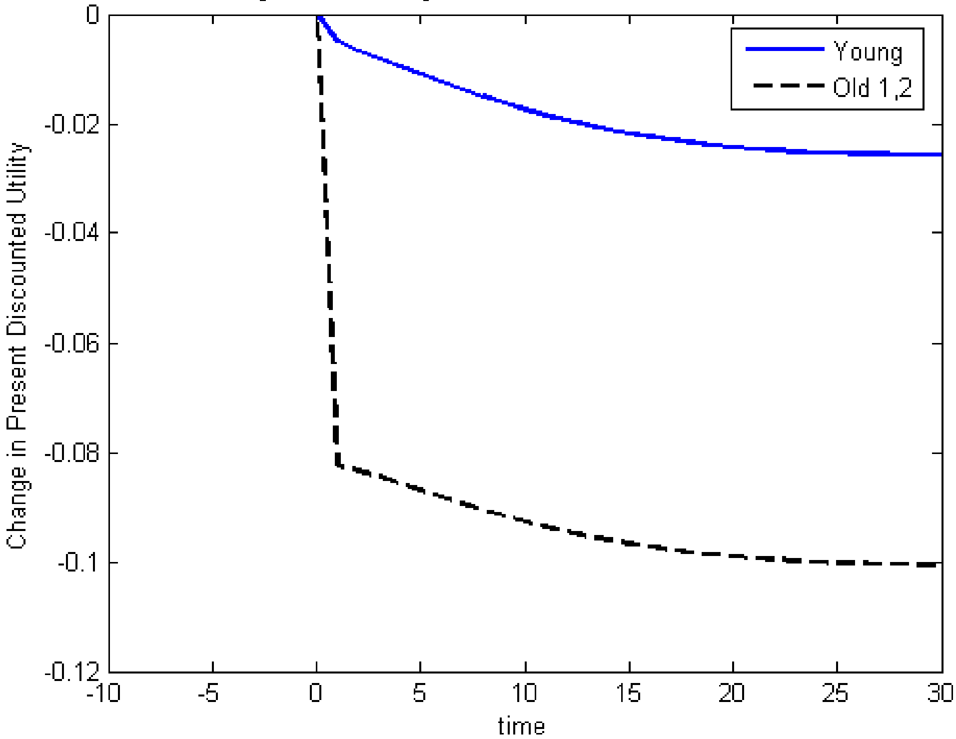


Figure 7.1: Change in Value of Construction Workers after Free Trade

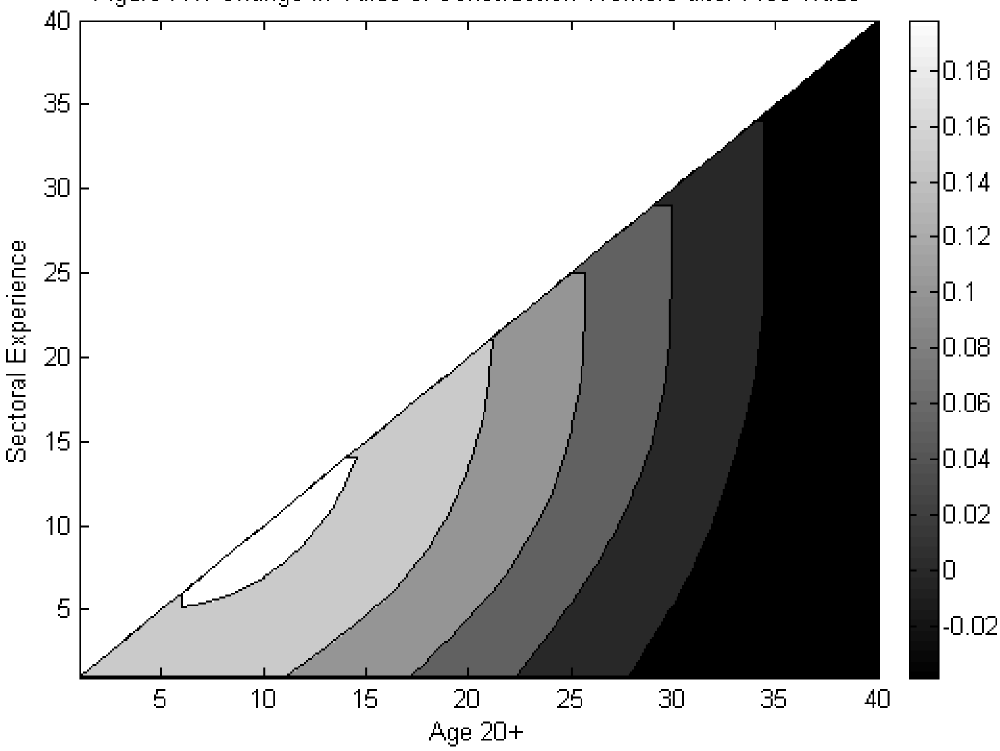


Figure 7.2: Change in Value of Manufacturing Workers after Free Trade

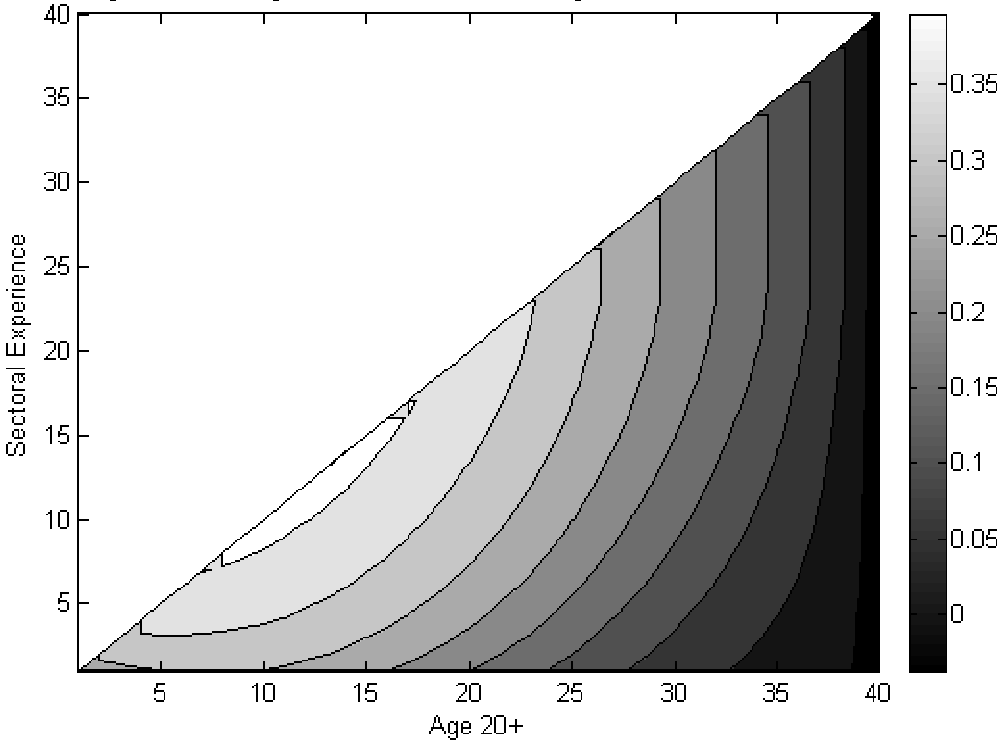


Figure 7.3: Change in Value of Metal Workers after Free Trade

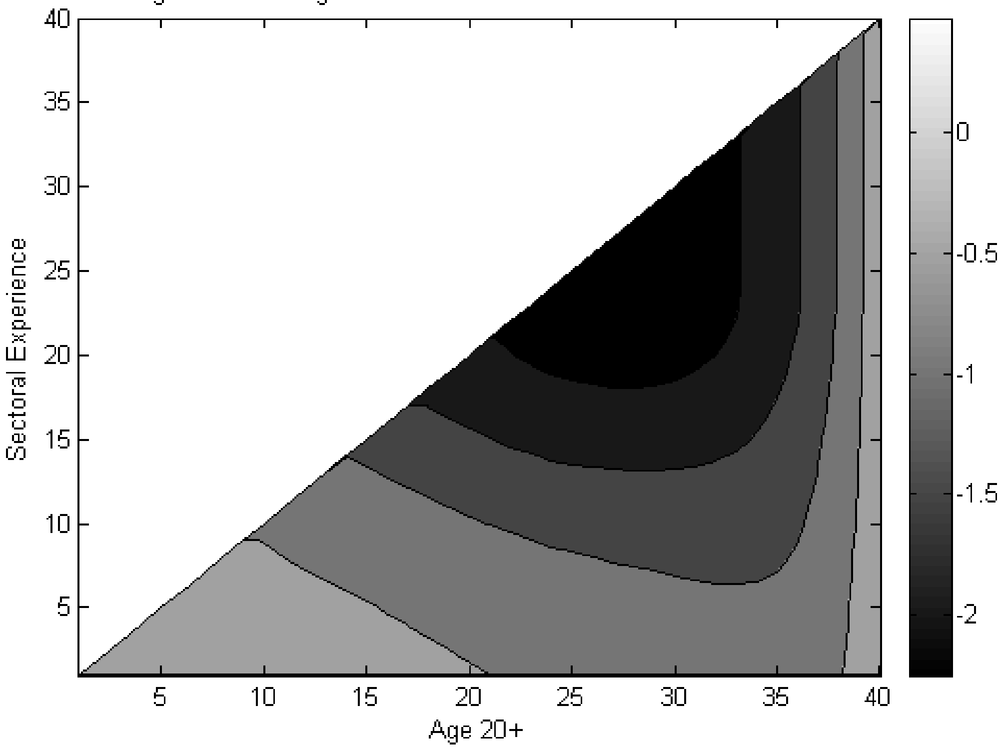


Figure 7.4: Change in Value of Service Workers after Free Trade

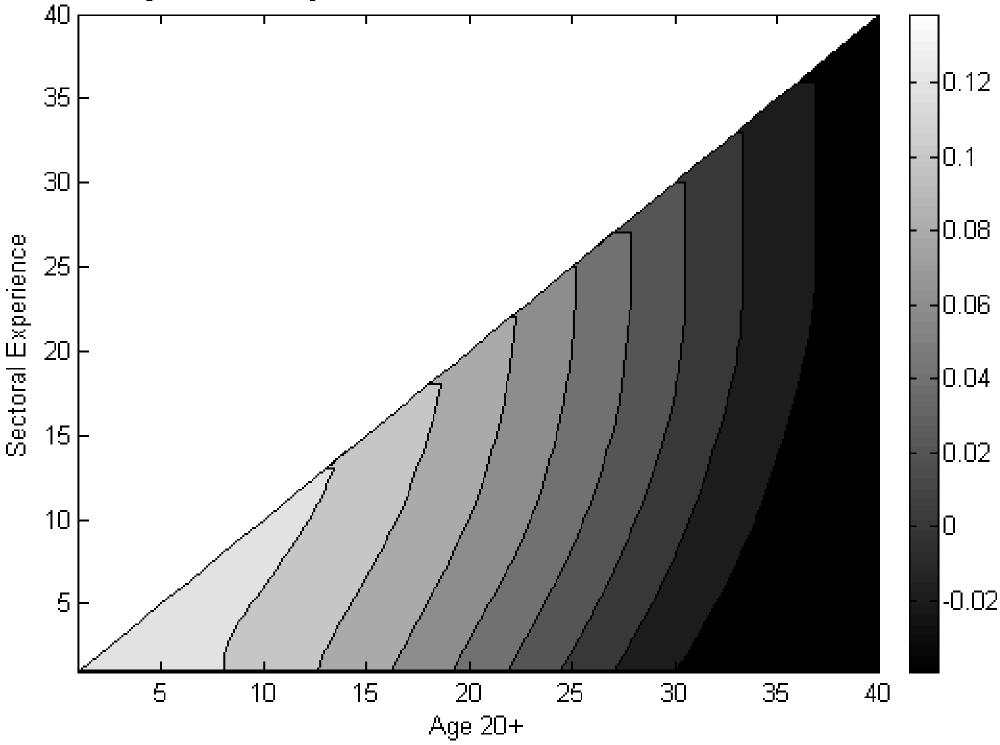


Figure 7.5: Change in Value of Trade Workers after Free Trade

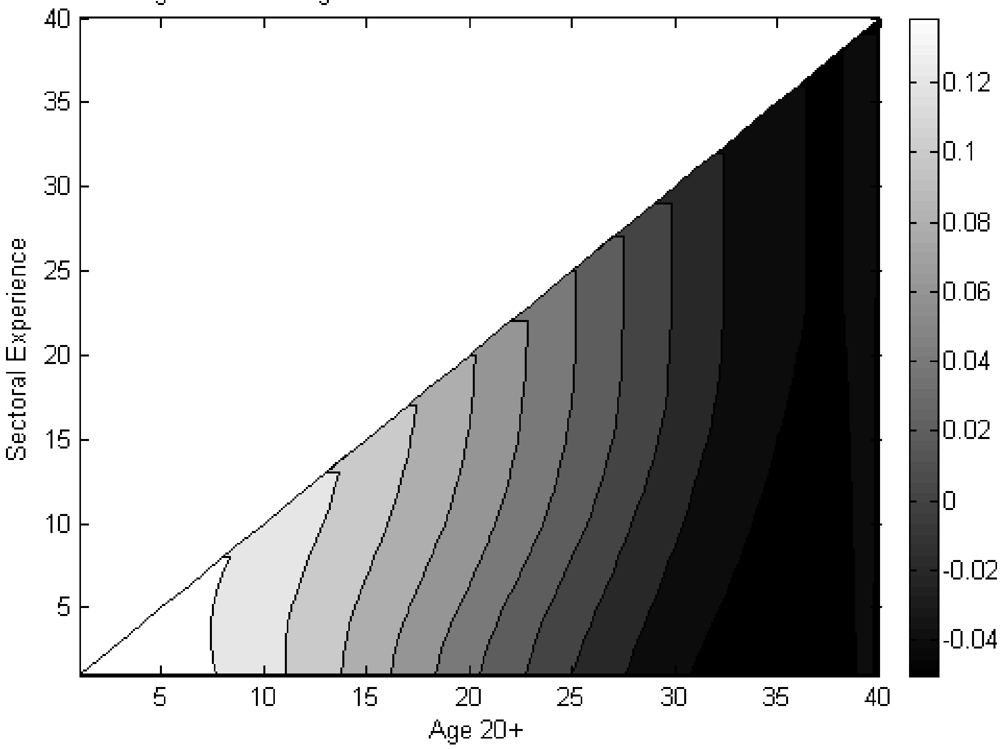


Figure 8.1: Change in Value of Construction Workers after Free Trade

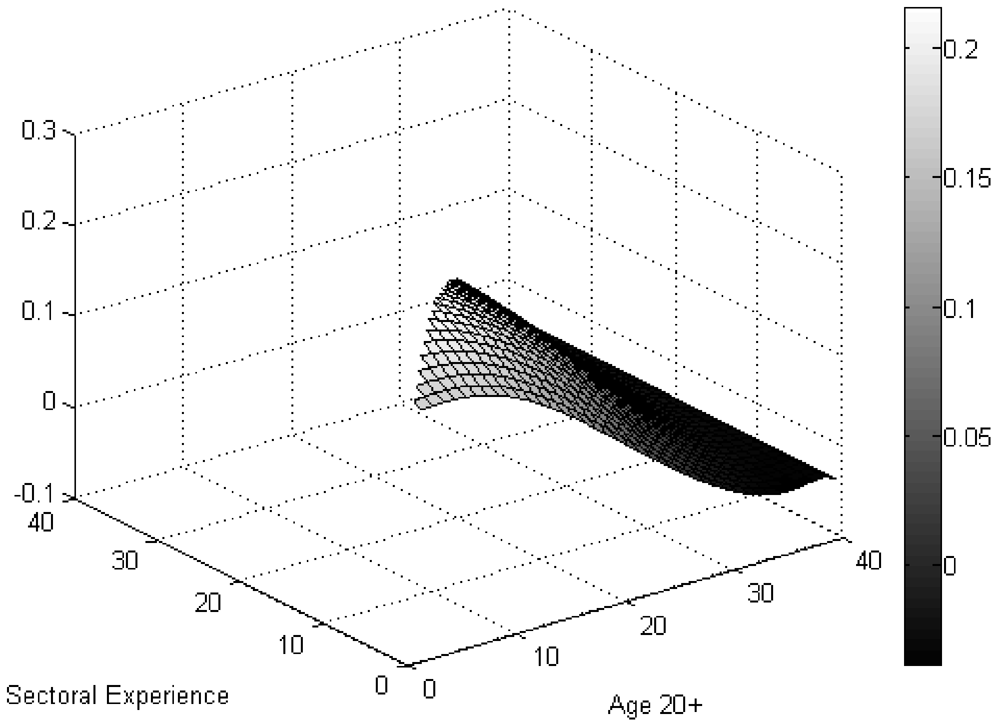


Figure 8.2: Change in Value of Manufacturing Workers after Free Trade

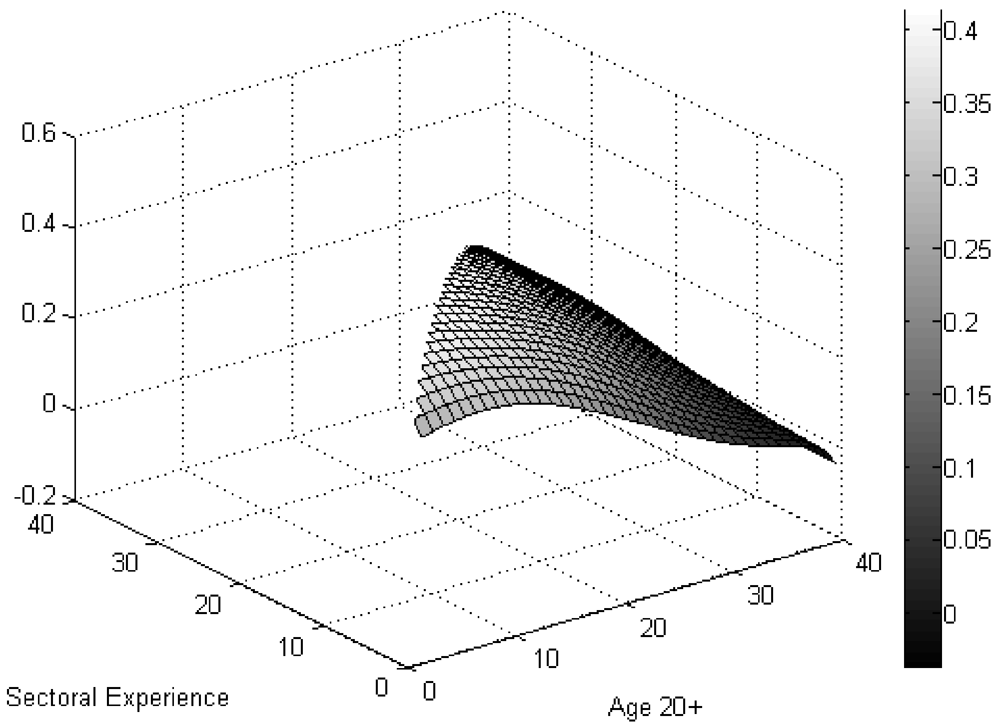


Figure 8.3: Change in Value of Metal Workers after Free Trade

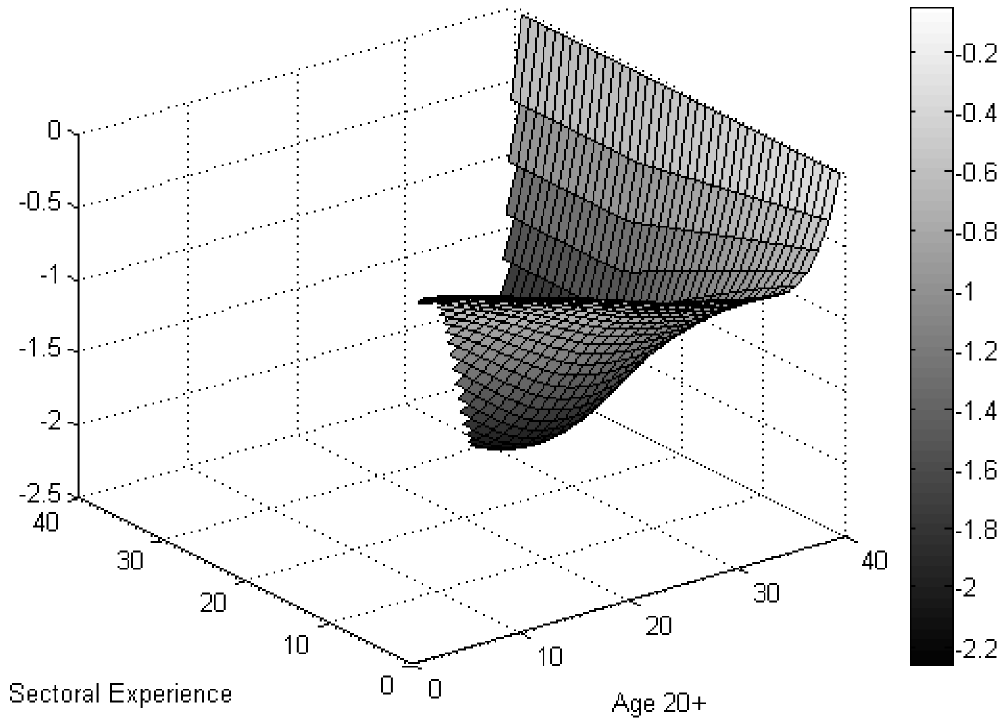


Figure 8.4: Change in Value of Service Workers after Free Trade

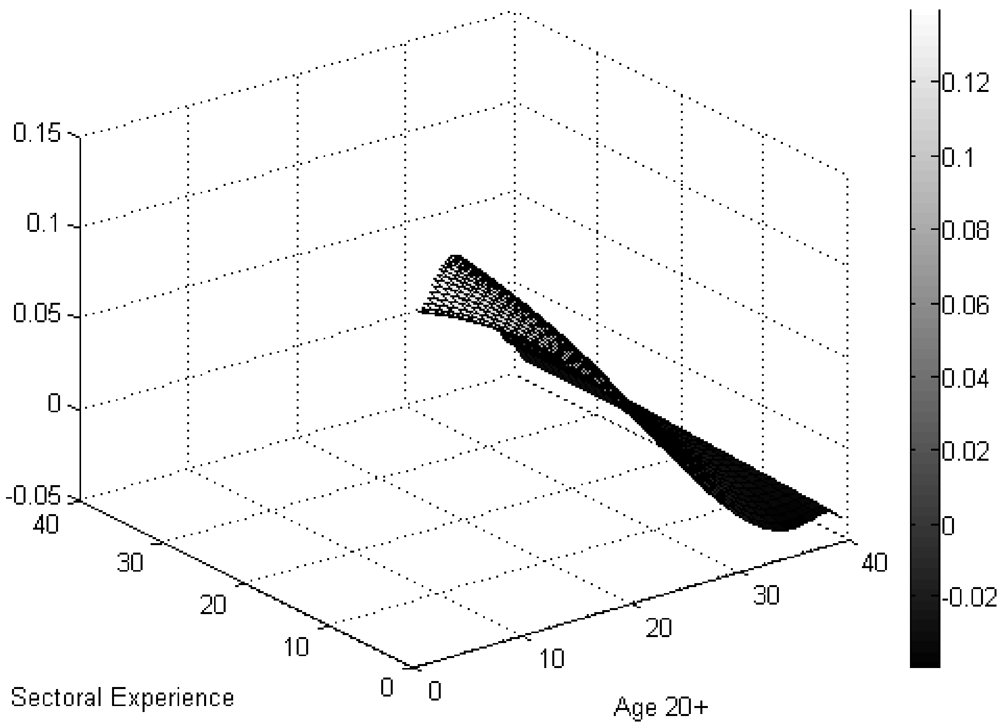


Figure 8.5: Change in Value of Trade Workers after Free Trade

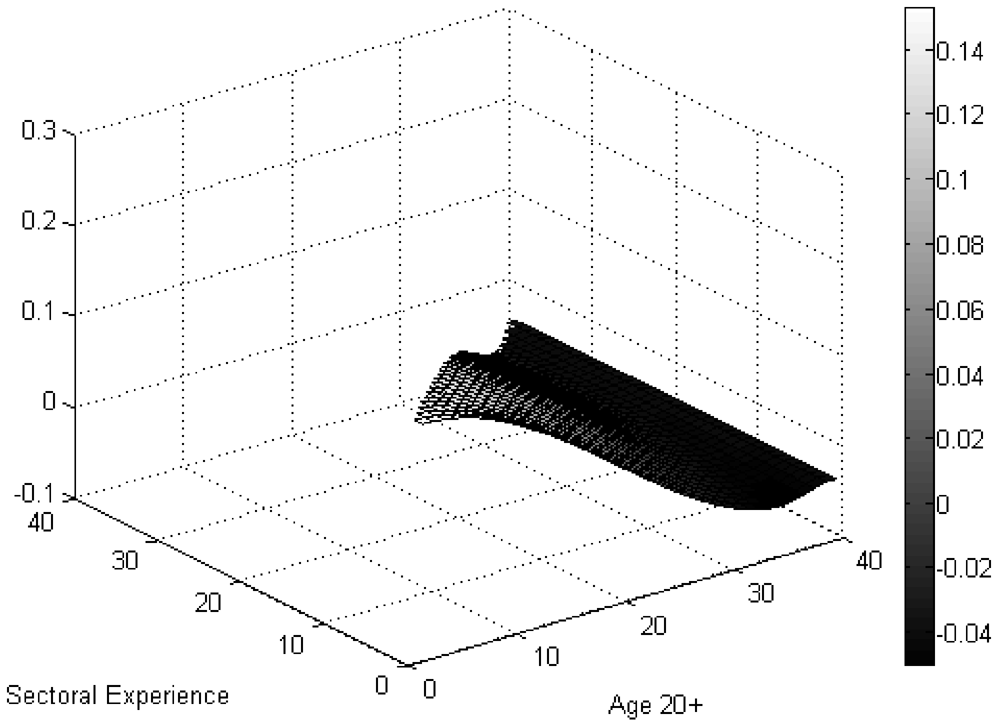


Figure 9.1: Change in Present Discounted Value of Wages - Construction

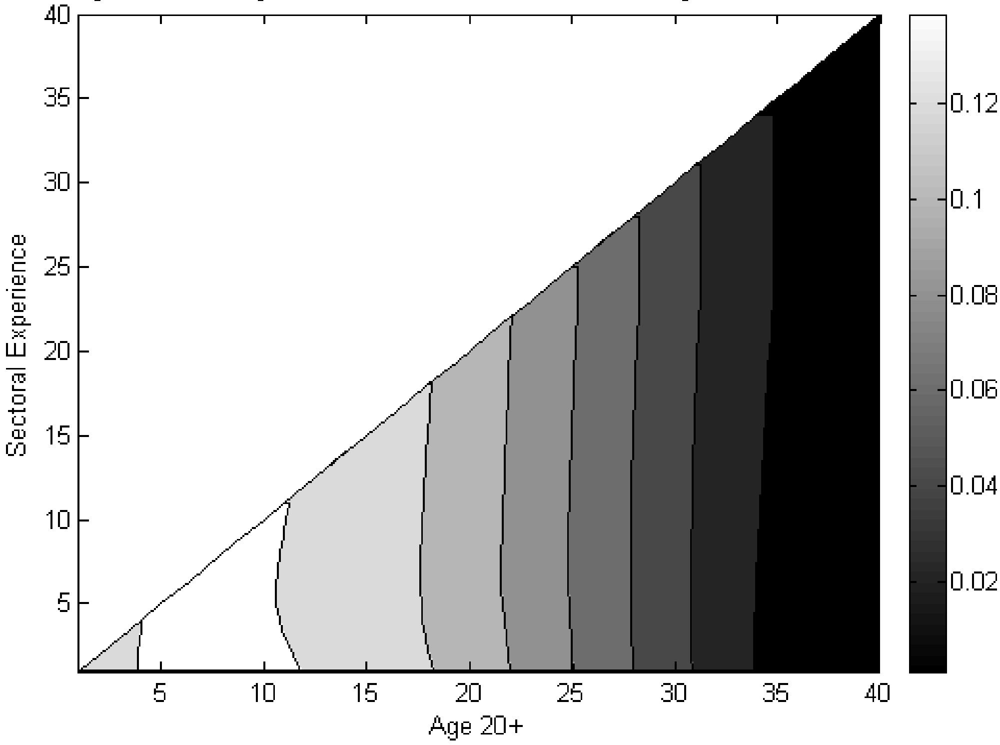


Figure 9.2: Change in Present Discounted Value of Wages - Manufacturing

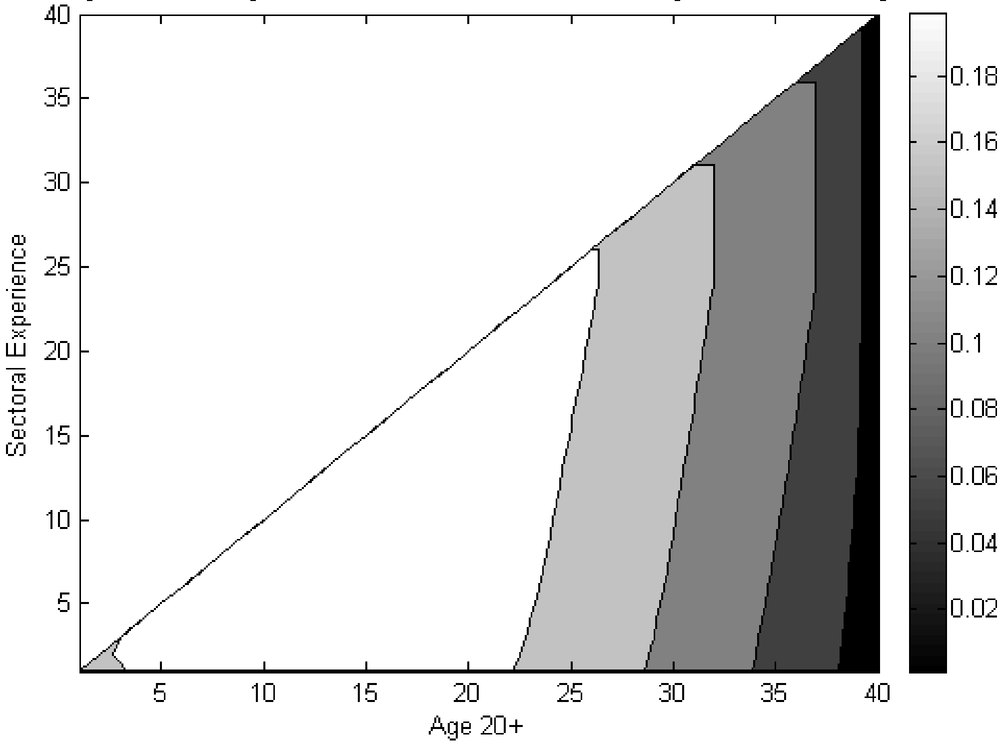


Figure 9.3: Change in Present Discounted Value of Wages - Metal

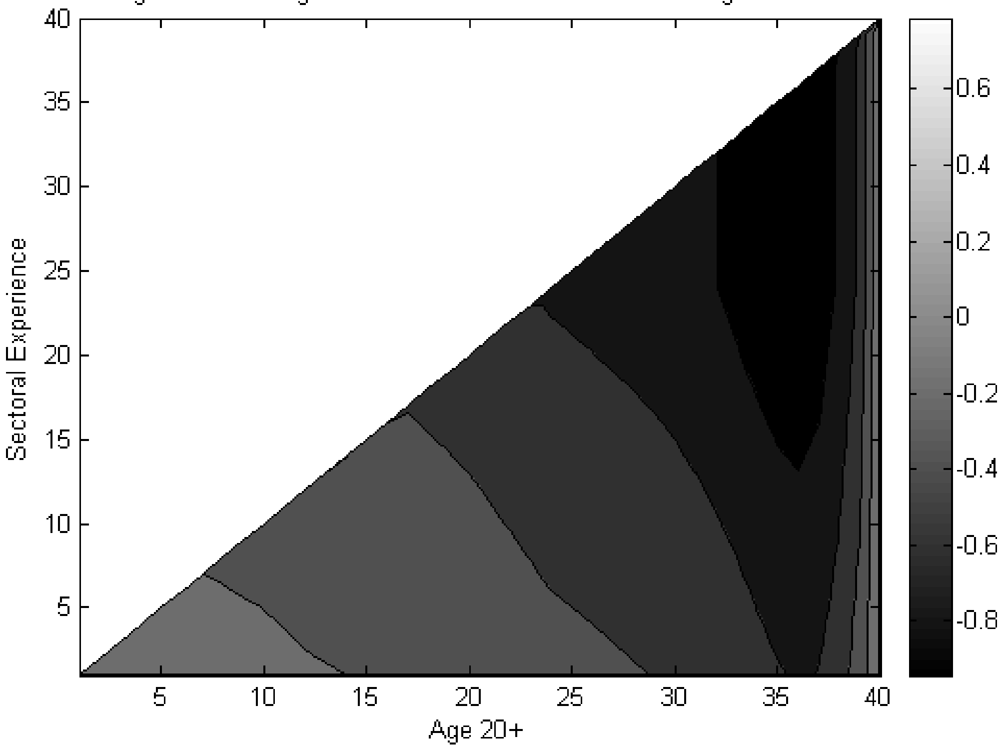


Figure 9.4: Change in Present Discounted Value of Wages - Service

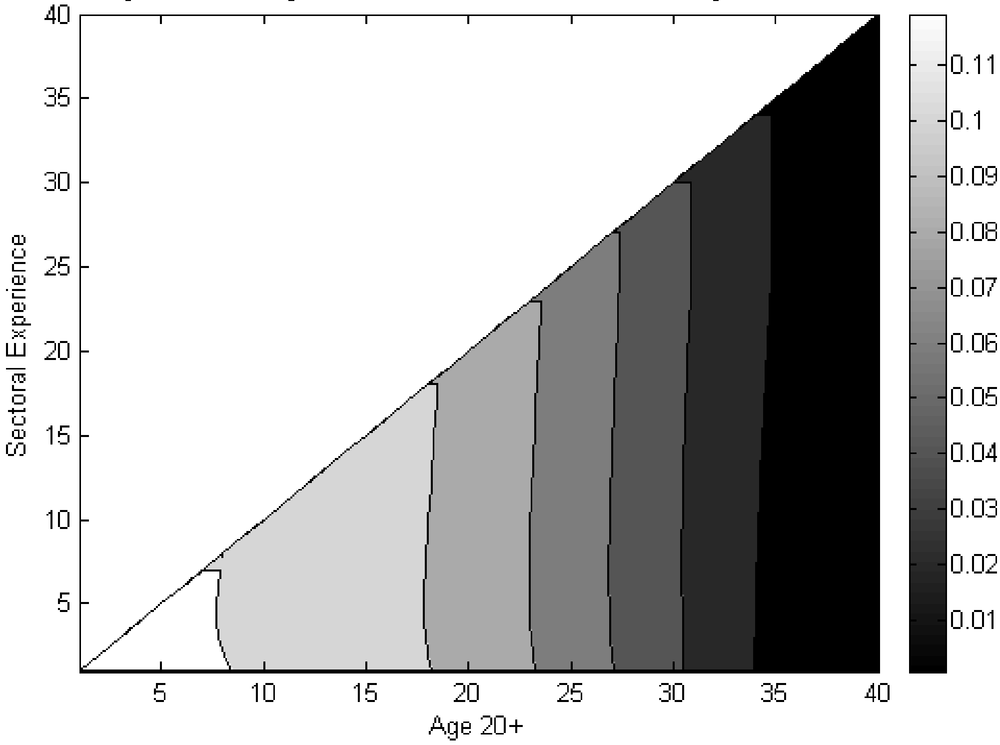


Figure 9.5: Change in Present Discounted Value of Wages - Trade

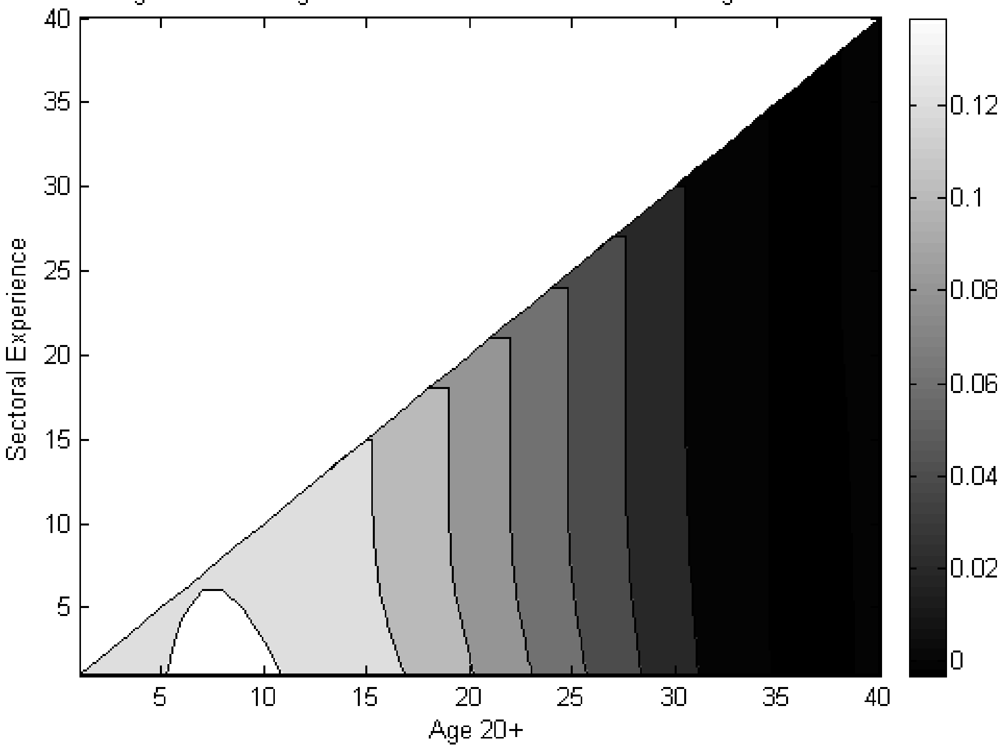


Figure 10.1: Change in Present Discounted Value of Wages - Construction

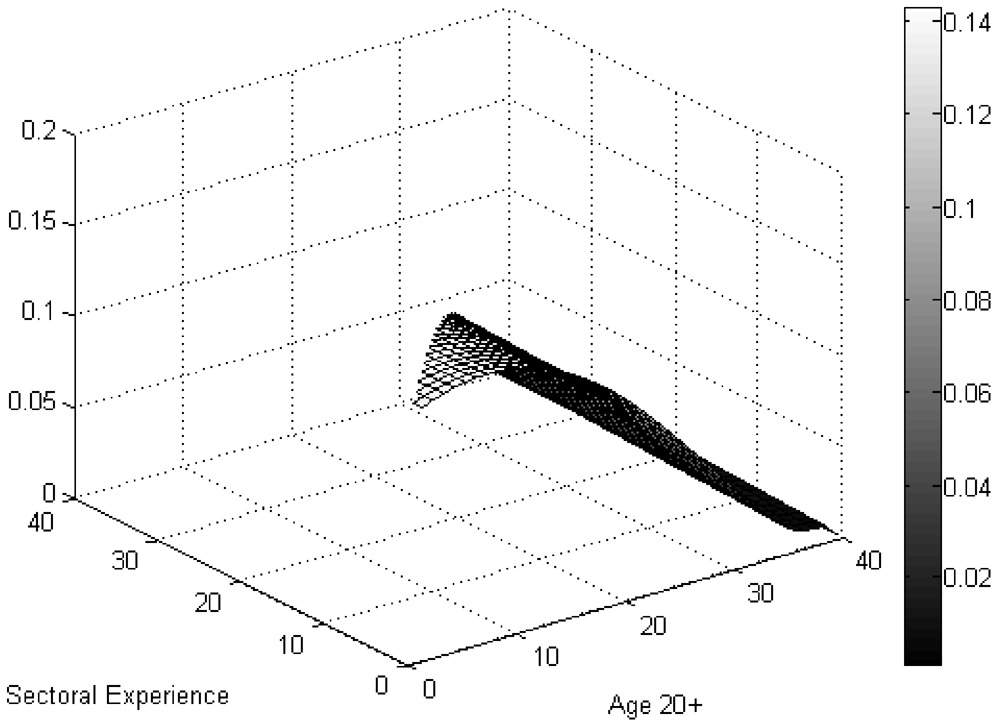


Figure 10.2: Change in Present Discounted Value of Wages - Manufacturing

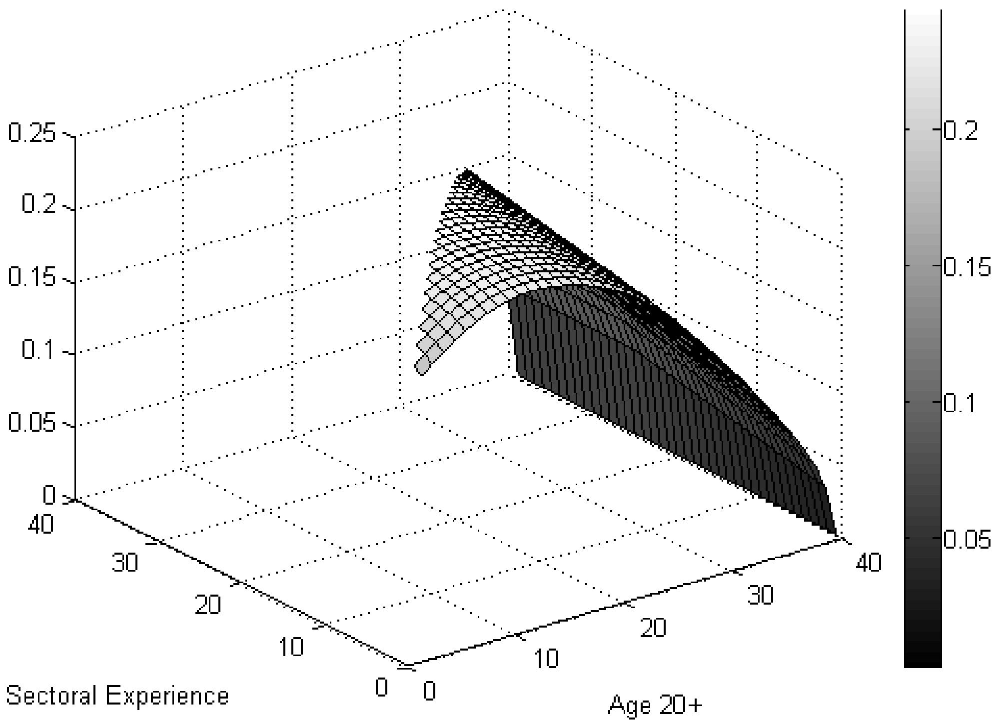


Figure 10.3: Change in Present Discounted Value of Wages - Metal

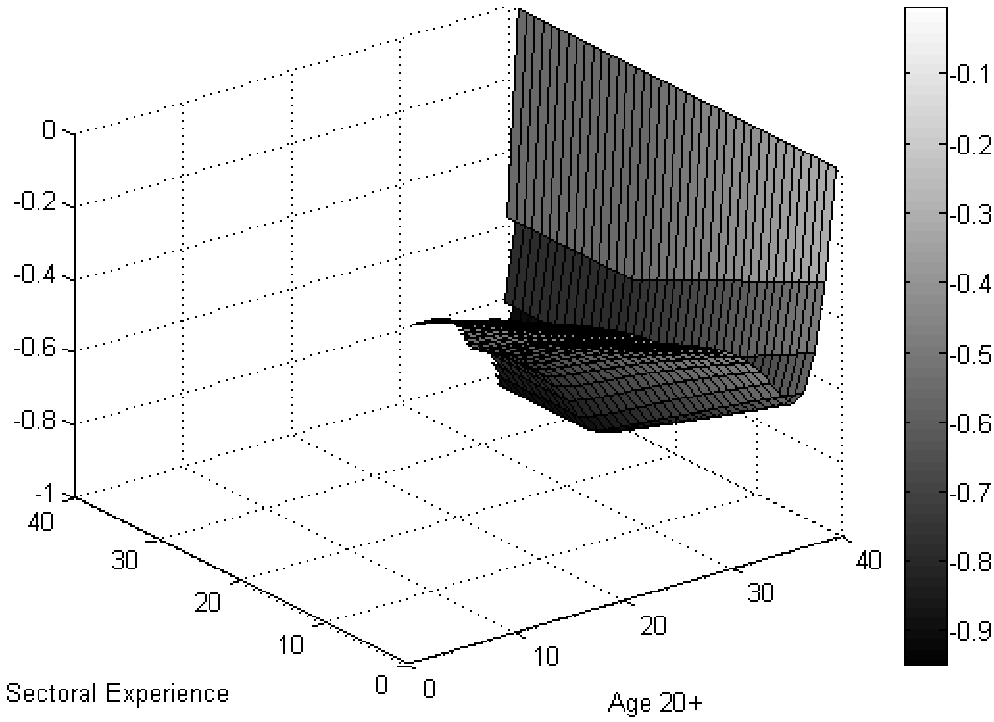


Figure 10.4: Change in Present Discounted Value of Wages - Service

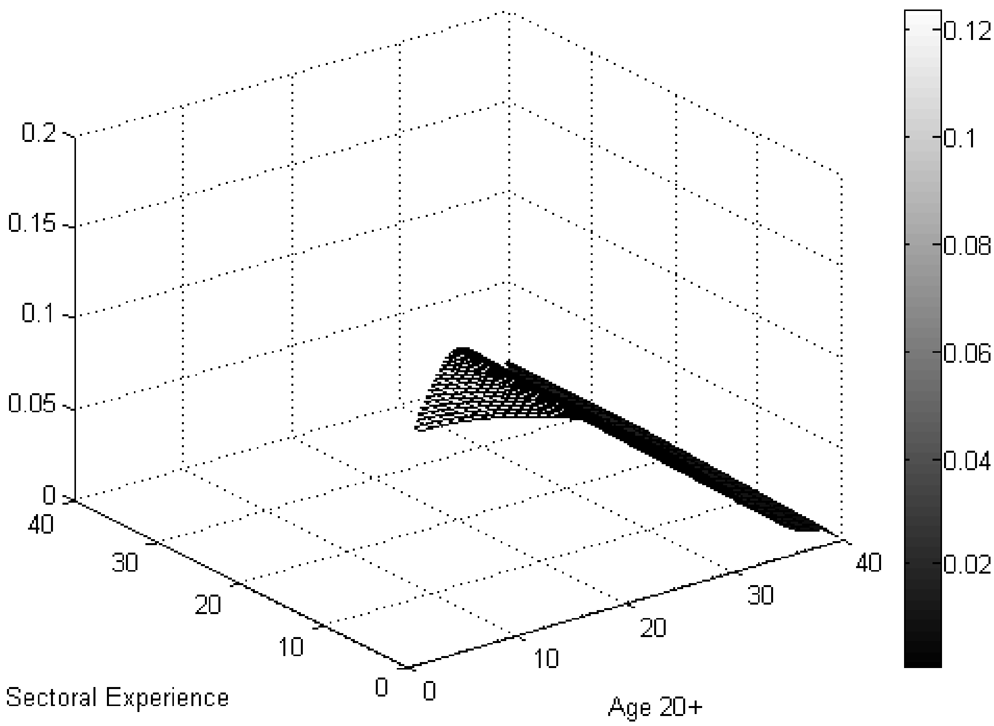


Figure 10.5: Change in Present Discounted Value of Wages - Trade

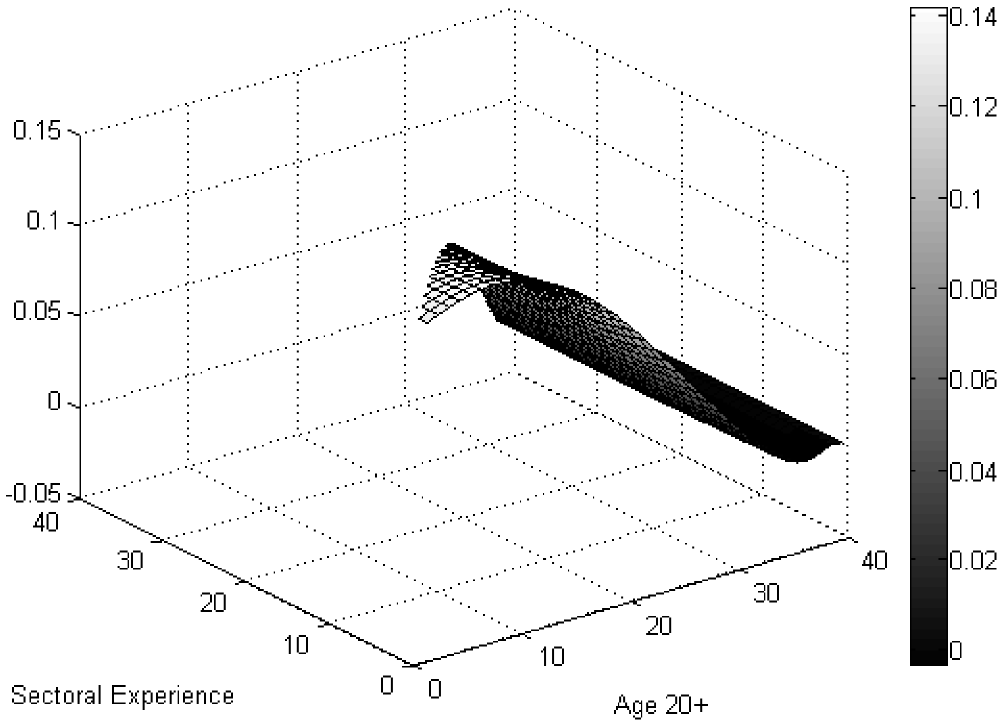


Figure 11.1: Percentage Change in Wages - Construction

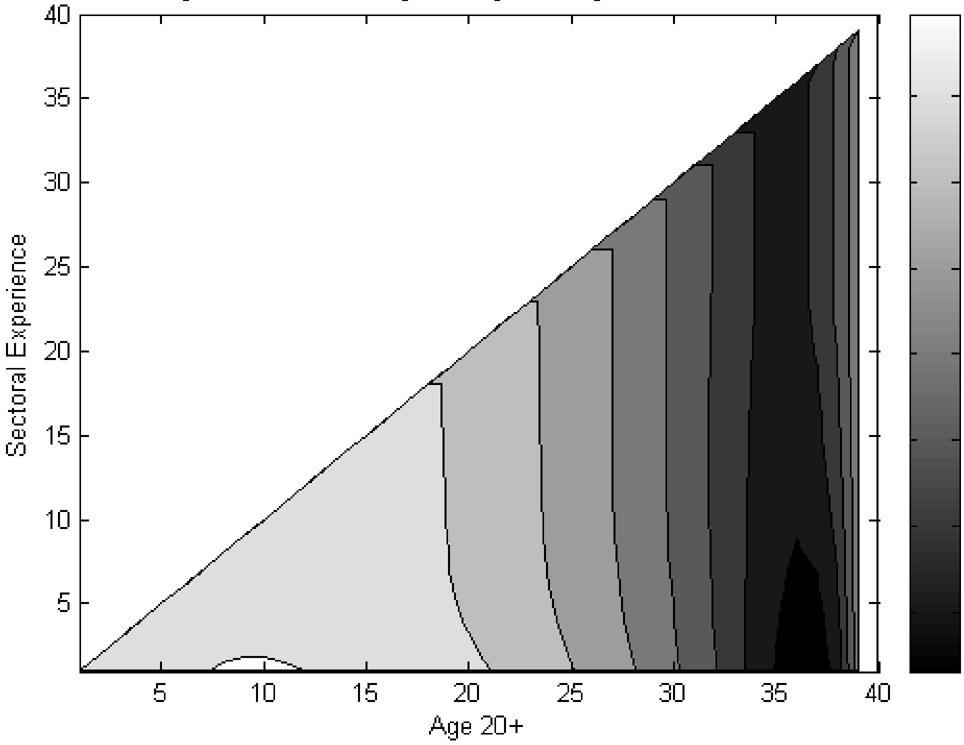


Figure 11.2: Percentage Change in Wages - Manufacturing

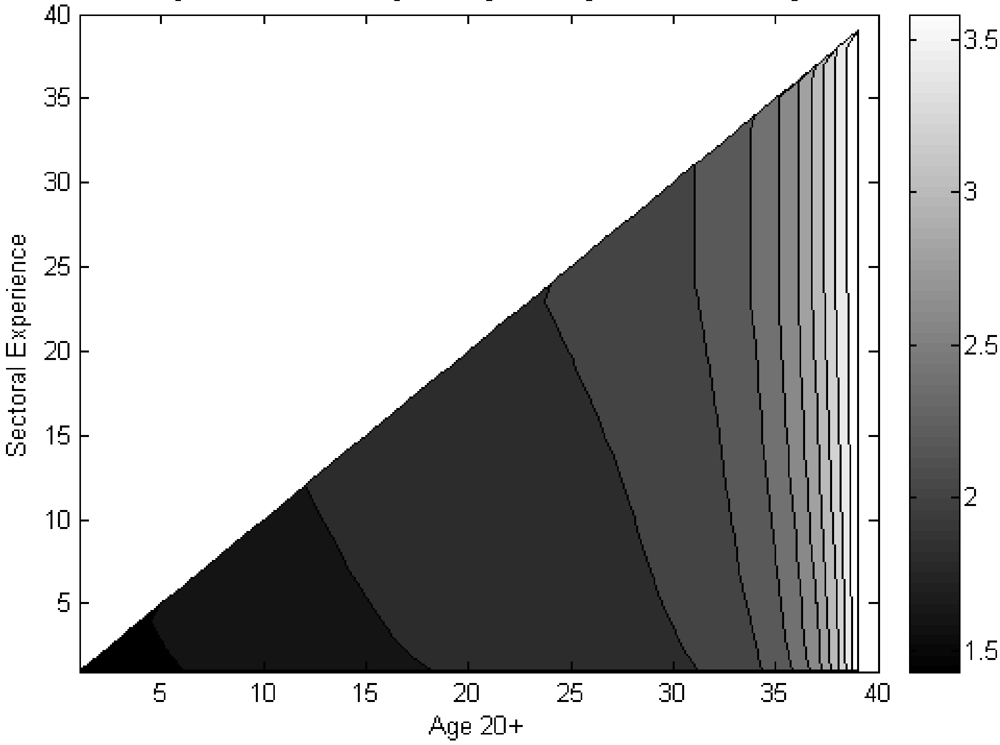


Figure 11.3: Percentage Change in Wages - Metal

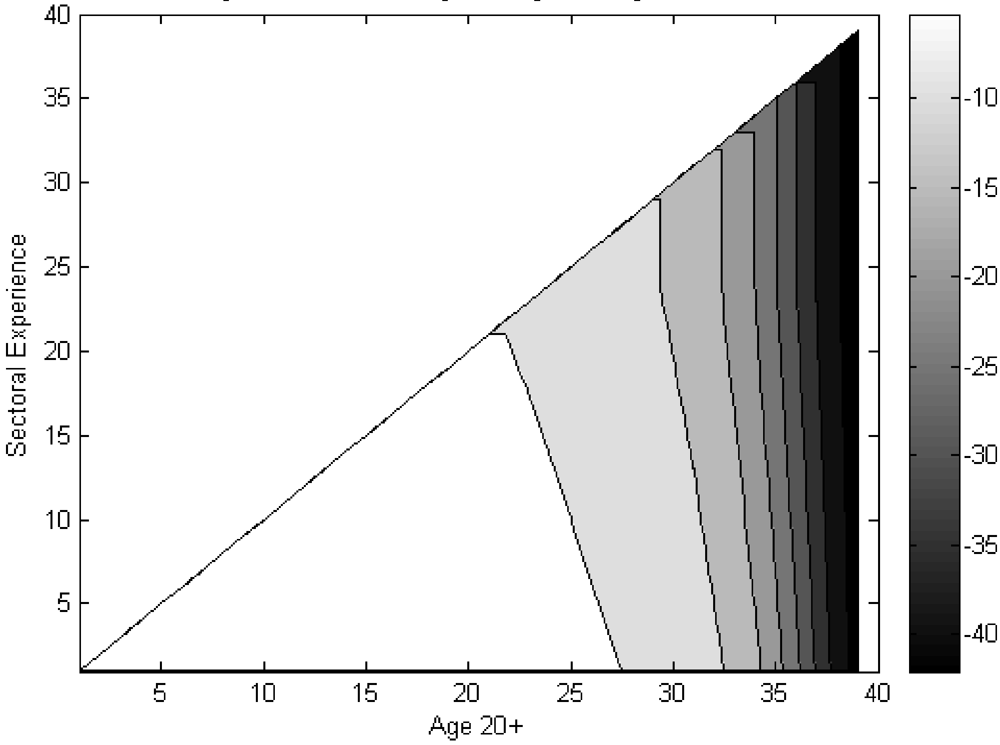


Figure 11.4: Percentage Change in Wages - Service

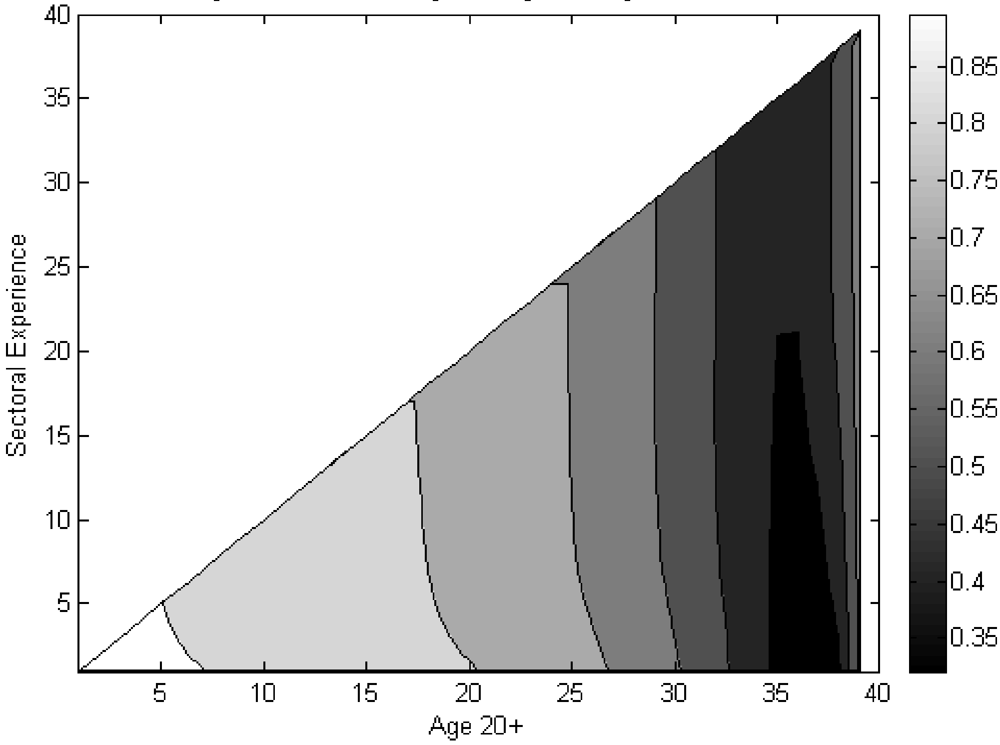


Figure 11.5: Percentage Change in Wages - Trade

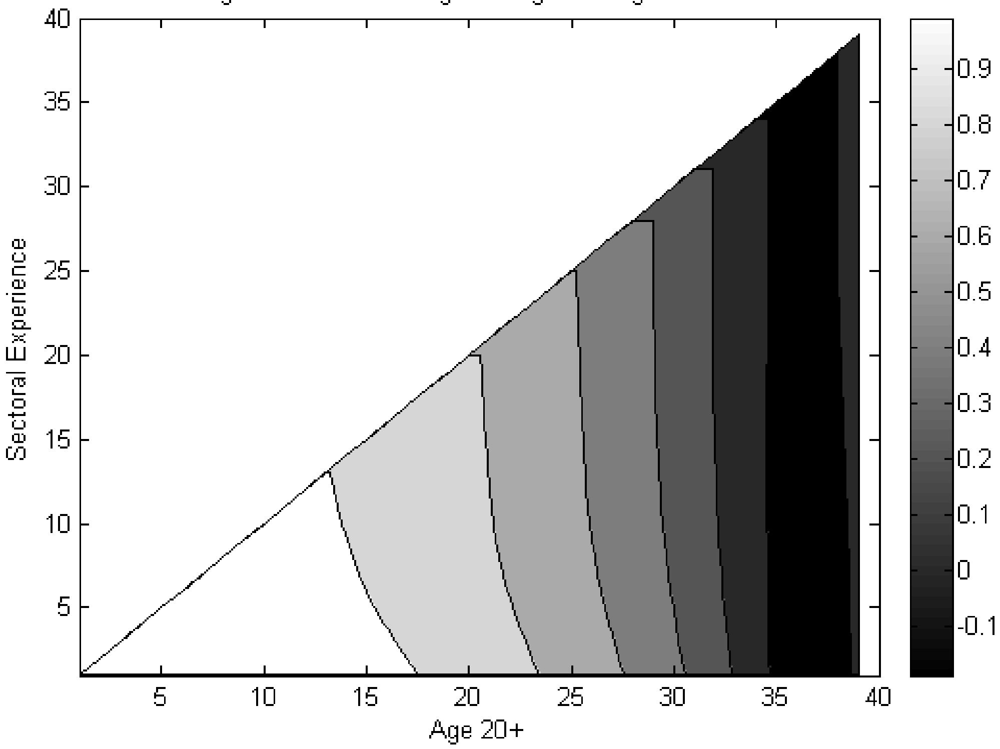


Figure 12.1: Percentage Change in Wages - Construction

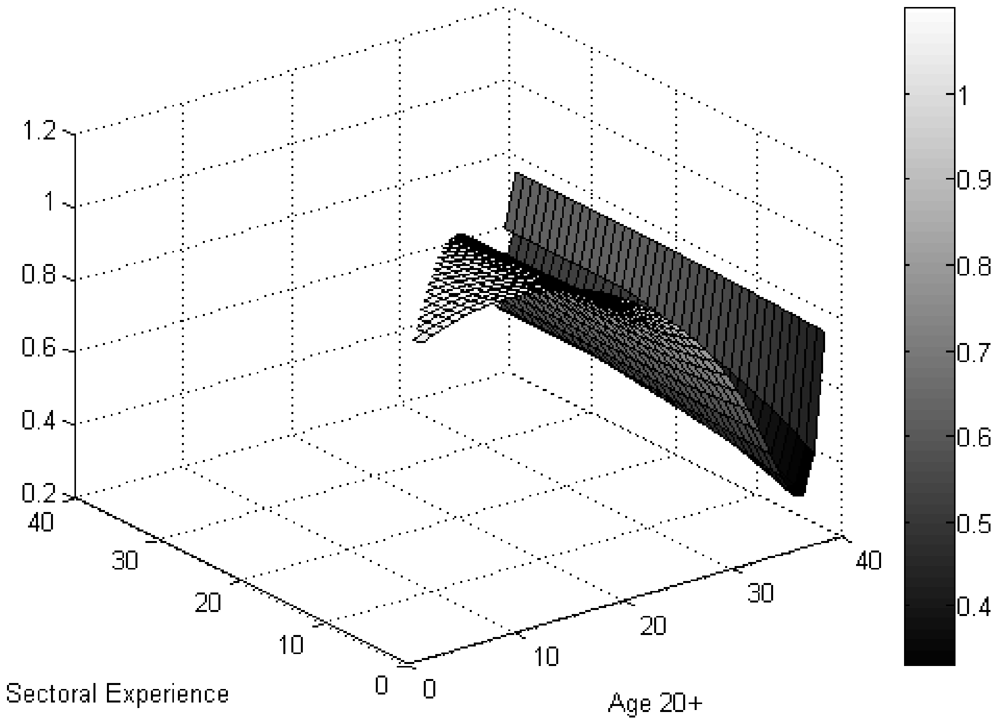


Figure 12.2: Percentage Change in Wages - Manufacturing

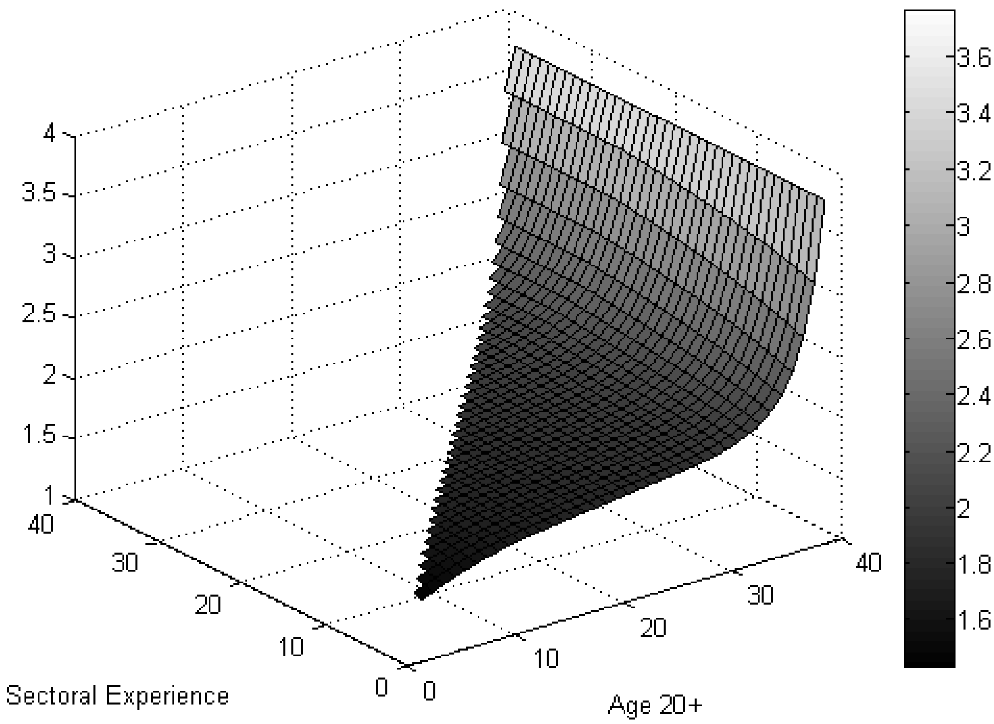


Figure 12.3: Percentage Change in Wages - Metal

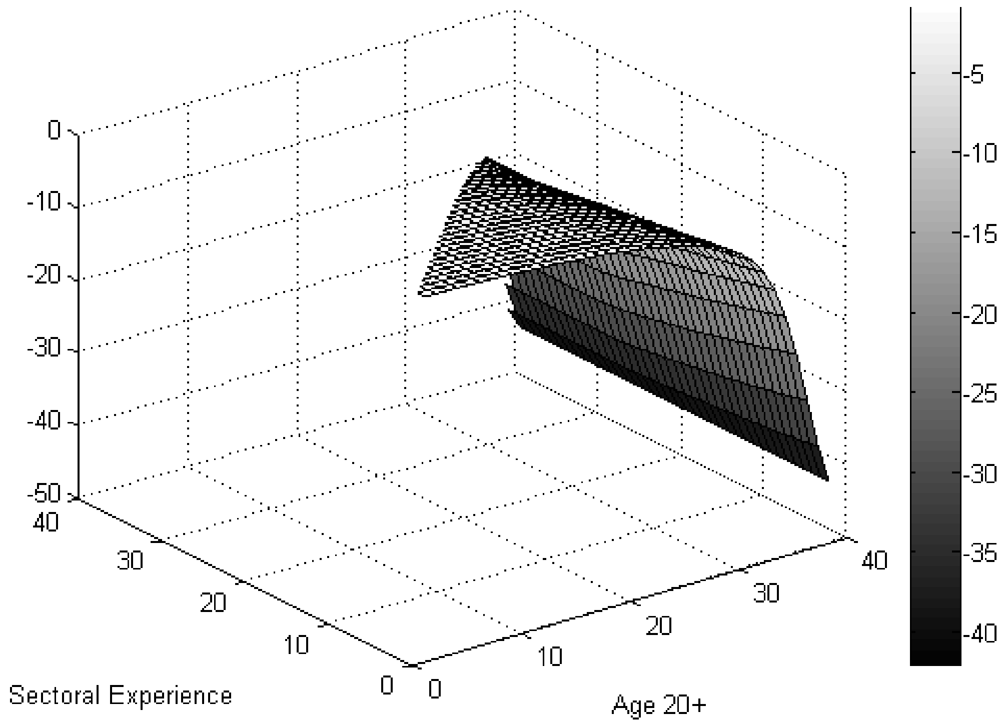


Figure 12.4: Percentage Change in Wages - Service

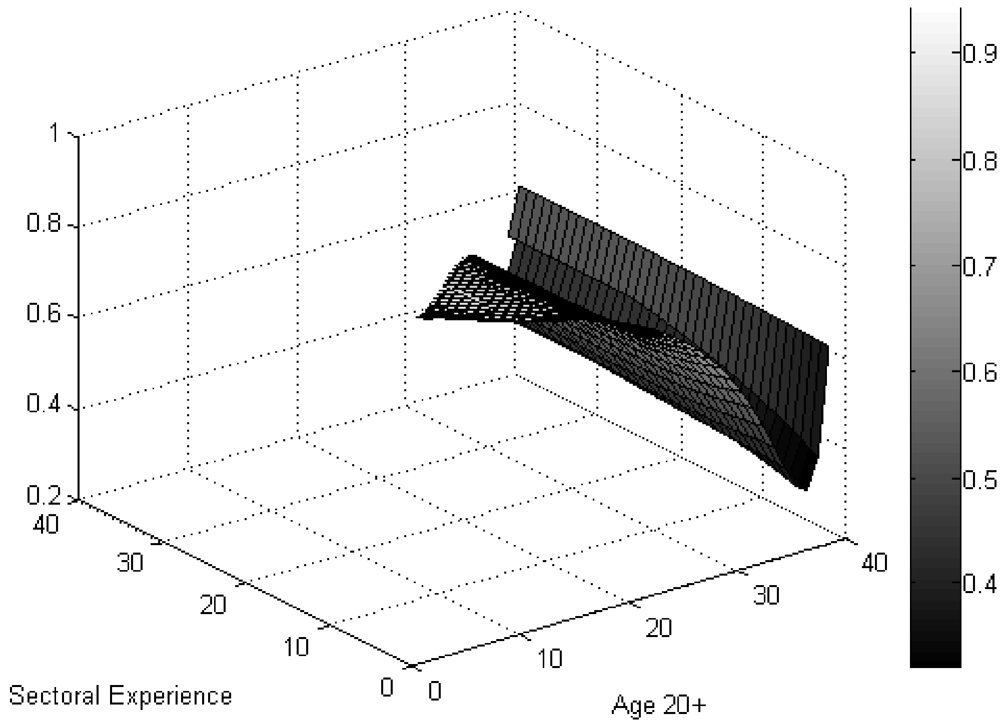


Figure 12.5: Percentage Change in Wages - Trade