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Monopsony and Discrimination in Labor Market in the Solow-Stiglitz Two-Group Neoclassical Growth Model[a]

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The purpose of this study is to deal with economic growth with labor market monopsony. The economy is composed of one sector (like in the Solow model) and two groups of households (like in the Stiglitz model). The sector uses capital and labor as inputs. Capital and output markets are perfectly competitive. The population is classified into two – discriminatory and discriminated – groups. Labor market for the discriminatory group is perfectly competitive, whereas it is characterized by monopsony for the latter group. We model the behavior of the household with the concept of disposable income and utility function developed by Zhang (2013, 2017). The model endogenously determines the profit of the firm which is equally distributed among the discriminatory population. We build the model and provide a computational procedure to quantify the response of the model economy in a comparative dynamic setting. We also compare the model outcomes with a labor market under perfect competition and under monopsony. We show that monopsony harms not only national economic growth but also the discriminatory household in the long term.

JEL codes: C61, D31, J42

Keywords: Solow model, Stiglitz model, Monopsony, Household heterogeneity, Income and wealth distribution

1 Introduction

In many contemporary economies, there are different forms of institutions, market structures, and great varieties of households. It is, therefore, important to develop a general analytical framework to analyze different economic interactions in an integrated manner. An important direction is obviously to integrate macroeconomics and microeconomics. Different microeconomic theories study efficiencies and equilibrium of different market structures in varied economic institutions (e.g. Nikaido, 1975; Dixit & Stiglitz, 1977; Shapiro, 1989; Mas-Colell et al., 1995; Chang, 2012; Parenti et al., 2017). Nevertheless, most of these studies are conducted with partial analytical frameworks. Little attention is paid to the achievements

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of microeconomics by macroeconomists. This study attempts to introduce some ideas in microeconomics into dynamic general equilibrium analysis. It makes a contribution to the economic growth theory by introducing monopsony in a labor market to neoclassical growth theory. This paper aims to make neoclassical growth theory more realistic by introducing different market structures in order to model the complex interactions of economic growth and market structures.

Among many forms of imperfection in labor markets (Booth, 2014), monopsony is one of the important forms. Monopsony theory was initiated by Joan Robinson in her famous The Economics of Imperfect Competition published in 1933 (Robinson, 1933; Thornton, 2004). The concept describes a market in which there is only a single purchaser. Labor market monopsony exists when firms are able to exercise powers over their suppliers of labor. A well-mentioned example is of a company which requires specified skills which no other companies require. A large company located in a town remote from other large cities may be the main employer, which empowers the company to set wages as workers are powerless in bargaining for better wages or working conditions. Manning (2003, 361) points out: "monopsony can provide a much better explanation than perfect competition of a wide range of labor market phenomena." Monopsony theory is examined and applied to different issues in different markets (Hirsch and Schumacher, 1995; Boal & Ransom, 1997; Atkinson & Kerkvliet, 1989; Bhaskar et al., 2002; Manning, 2006, 2010; Ashenfelter et al., 2010; Muehlemann et al., 2013; Bachmann & Frings, 2017). For instance, Webber (2016) applies employer-employee data to find firm-based gender-specific labor supply elasticities and interprets the empirical findings with broad concepts of monopoly. One also finds relevant literature related to monopoly and gender wage gaps. Hirsch et al. (2018) empirically test the implications of monopsony theory for workers' wages over business cycles. They find that firms exert more monopsony power during economic downturns. There are other studies on employer's monopsony power in labor markets (e.g. Hirsch and Schumacher (1995) and Ashenfelter et al. (2010)). It should be noted that there is little attention paid to labor market monopsony in the literature of formal growth theory. An exception is by Barr & Roy (2008) who propose a growth model with imperfect labor markets. Rather than one buyer in the labor market, as is the case in this study, they deal with labor markets with different firms facing upward-rising supply curves for labor. Monopolistic competition exists because there is a minimum efficient scale of production and costs of workers for traveling to working places (designed as in traditional urban economics, e.g. Salop (1979) and Helsley & Strange (1990)). Their model takes into account the endogeneity of human capital by maximizing lifetime utility according to the Ramsey. This paper makes another contribution to the literature by integrating monopsony theory with the Walrasian general equilibrium theory and the neoclassical growth theory.

We build a one-sector two-group growth model to integrate labor market monopsony and dynamics of wealth and income distribution in neoclassical growth theory. Following traditional neoclassical growth theory (e.g. Solow, 1956; Uzawa, 1961; Burmeister & Dobell, 1970; Azariadis, 1993; Barro & Sala-i Martin, 1995; Jensen & Larsen, 2005; Zhang, 2008), we consider capital accumulation as the main engine of economic growth. It should be noted that the dynamics of income and wealth are the main concerns of post-Keynesian theory of growth and distribution (Pasinetti, 1962; Salvadori, 1991). In Post-Keynesian growth theory, Stiglitz (1967) proposes a growth model of two classes. The Stiglitz model synthesizes the post-Keynesian theory and Uzawa's two-sector model. But there are few further studies along the research line. This study attempts to make a theoretical contribution to modeling economic growth with perfectly competitive as well as imperfectly competitive market structures in a dynamic analytical general equilibrium framework. We introduce monopsony to neoclassical growth theory with Zhang (2013, 2017)'s concept of disposable income and utility function. We frame the model within the Solow-Stiglitz two-group growth model. The economy is composed of one sector (like in the Solow model) and two groups of households (like in the Stiglitz model). Another theory closely related to our modelling framework is Walrasian general equilibrium (Walras, 1874; Arrow & Hahn, 1971; Arrow, 1974). Despite some attempts in the literature, quite a few numbers of researchers have become successful in introducing endogenous wealth formally into the theory (e.g. Dana et al., 1989; Montesano, 2008; Impicciatore et al., 2012). Zhang (2013, 2017) introduces wealth into Walrasian general equilibrium theory with a new definition of disposable income and utility function. This study is an extension of these works on general equilibrium theory.

This paper is organized as follows. Section 2 develops the basic growth model with monopsony in the labor market. Section 3 examines the dynamic properties of the model for the given initial values of variables and parameters towards its steady-state. Section 4 carries out five different simulations driven by changes in model parameters and summarizes the impacts in a comparative dynamic setting. Section 5 compares the dynamics of the model with monopsony and the model with perfect competition. Section 6 concludes.

2 The Basic Model

We introduce monopsony into the Solow-Stiglitz neoclassical two-group growth model with the wealth of households. The definition of households' disposable income and the functional forms of utility functions are extended due to the inclusion of the level of wealth by following Zhang (2013, 2017). Most of our model is constructed within the Solow-Stiglitz growth model, except for the behavior of the household and the behavior of the monopsonist.

There are two factors of production, capital and labor. Capital and output markets are perfectly competitive. The population is disaggregated into two groups; discriminatory and discriminated households. Labor market for the former group is perfectly competitive, whereas the latter group's labor market is characterized by monopsony. A representative firm maximizes its profit in deciding output and the optimal combination of inputs.

The modelling of monopsony is based on the traditional monopsony theory. The model endogenously determines the profit of the firm which is equally distributed among the discriminatory population. We use subscript $j = 1, 2$ to denote the discriminatory group and discriminated group, respectively. Each group has a fixed population, denoted by $\bar{N}_j$. Following the Solow model, we consider that there is only one sector which produces capital goods for consumption and investment. Capital depreciates exponentially at a constant rate $\delta_k \in (0, 1)$. Households own assets of the economy and allocate their incomes between consumption and saving. Factors of production are fully employed in every time period. The total savings is equal to the sum of households' savings.

Let prices be measured in terms of the commodity and the price of the commodity be unity, i.e. the price of output is the numeraire of the system. We denote the wage rate of worker j and the interest rate by $w_j(t)$ and $r(t)$, respectively. We use $T_j(t)$ to stand for work time of worker j and the total capital stock is denoted by $K(t)$. The total labor supply, $N(t)$, is a weighted sum of two household groups' populations such that

$$N(t) = h_1\ T_1(t)\ \bar{N}_1 + h_2\ T_2(t)\ \bar{N}_2 \tag{1}$$

where h_j is the human capital of group j. We assume that h_j is constant in this study.

Current income and disposable income

In this study, we use an alternative approach in modeling behavior of households proposed by Zhang (1993, 2005). Let $\bar{k}_j(t)$ stands for the wealth of household j. We have $\bar{k}_j(t) = \bar{K}_j(t)\bar{N}_j$, where $\bar{K}_j(t)$ is the total wealth held by group j. The profit of the firm is distributed between the population of the discriminatory household group. In other words, it is assumed that the discriminated household receives no profit, i.e. $\pi_2(t) = 0$.[1] Per capita current income is the sum of the interest payment, $r(t)\bar{k}_j(t)$, the wage payment, $W_j(t) = h_j T_j(t) w_j(t)$, and the profit income.

$$y_j(t) = r(t)\ \bar{k}_j(t) + W_j(t) + \pi_j(t) \tag{2}$$

The disposable income, $\hat{y}_j(t)$, however, is the sum of the current income and the value of wealth. That is:

$$\hat{y}_j(t) = y_j(t) + \bar{k}_j(t) \tag{3}$$

Budget constraint and utility function

The disposable income of household j is used for saving, $s_j(t)$, and consumption, $c_j(t)$. It is assumed that wealth can be sold and used for consumption without any transaction costs and time delays. This implies that the household has the disposable income to distribute. The budget constraint is thus given by:

$$c_j(t) + s_j(t) = \hat{y}_j(t) \tag{4}$$

It should be noted that saving in this study is from the disposable income including the wealth of households by following Zhang (2008). Therefore, the concept differs from the traditional definition of saving (for instance, in the Solow model) which is from the current period's disposable income. Each household has equal constant available time, T_0, for working, $T_j(t)$, and for leisure, $\bar{T}_j(t)$. We have the time constraint:

$$T_j(t) + \bar{T}_j(t) = T_0 \tag{5}$$

Inserting (3) and (5) in (4) ends up with

$$h_j\ \bar{T}_j(t)\ w_j(t) + c_j(t) + s_j(t) = \bar{y}_j(t) \equiv R_t\ \bar{k}_j(t) + h_j\ T_0\ w_j(t) + \pi_j(t) \tag{6}$$

where $R(t) \equiv 1 + r(t)$. We call $\bar{y}_j(t)$ the potential disposable income of household when the representative household spends all the available time on working. Each household has three variables to decide, $\bar{T}_j(t)$, $c_j(t)$, and $s_j(t)$ to maximize the level of utility, $U_j(t)$:

$$U_j(t) = \bar{T}_j^{\sigma_{j0}}\ c_j^{\xi_{j0}}\ s_j^{\lambda_{j0}}$$

[1] As shown in the rest of the paper, we can easily relax this assumption.

where σ_{j0} is the propensity to use leisure time, ξ_{j0} is the propensity to consume goods, and λ_{j0} is the propensity to save, and all are positive parameters.

Optimal household behavior

Maximizing the utility subject to (6) yields the optimal levels of leisure, consumption, and saving:

$$h_j \ \bar{T}_j(t) \ w_j(t) = \sigma_j \ \hat{y}_j(t), \quad c_j(t) = \xi_j \ \hat{y}_j(t), \quad s_j(t) = \lambda_j \ \hat{y}_j(t) \tag{7}$$

where $\sigma_j \equiv \sigma_{j0}\rho_j$, $\xi_j \equiv \xi_{j0}\rho_j$, $\lambda_j \equiv \lambda_{j0}\rho_j$, and $\rho_j \equiv \frac{1}{\sigma_{j0}+\xi_{j0}+\lambda_{j0}}$.

Wealth accumulation

According to the definition of $s_j(t)$, the change in the household's wealth is given by

$$\dot{\bar{k}}_j(t) = s_j(t) - \bar{k}_j(t) \tag{8}$$

This equation states that the change in wealth is equal to saving minus dissaving.

Production

Let $F(t)$ stands for production function. We use the Cobb-Douglas technology

$$F(t) = AK^{\alpha}(t) \ N^{\beta}(t) \tag{9}$$

where A, α, and β are positive parameters and $\alpha + \beta = 1$. Firm takes the discriminatory household's wage rate as given and decides group 2's wage rate. From (7), we have

$$w_2(t) \ = \ \frac{\sigma_2 \ R_t \ \bar{k}_2(t)}{(\widetilde{\sigma} - T_2(t)) \ h_2} \tag{10}$$

where $\widetilde{\sigma} \equiv (1-\sigma_2)\,T_0$. The profit is given by:

$$\pi(t) = F(t) - (r(t) + \delta_k)\,K(t) - w_1(t) \ h_1 \ T_1(t) \ \bar{N}_1 - w_2(t) \ h_2 \ T_2(t) \ \bar{N}_2 \tag{11}$$

Insert (10) in (11)

$$\pi(t) = F(t) - R_\delta(t) \ K(t) - w_1(t) \ h_1 \ T_1(t) \ \bar{N}_1 - \frac{\widetilde{R}(t) \ T_2(t)}{\widetilde{\sigma} - T_2(t)} \tag{12}$$

where $\widetilde{R}(t) \equiv \sigma_2 \ R(t) \ \bar{k}_2(t) \ \bar{N}_2$ and $R_\delta(t) \equiv r(t) + \delta_k$. The first-order conditions for maximizing the profit are as follows.

$$\begin{aligned} \frac{\partial \pi(t)}{\partial K(t)} &= \frac{\alpha \ F(t)}{K(t)} - R_\delta(t) = 0 \\ \frac{\partial \pi(t)}{\partial T_1(t)} &= \frac{\beta F(t)}{N(t)} \ h_1 \bar{N}_1 - w_1(t) \ h_1 \ \bar{N}_1 = 0 \\ \frac{\partial \pi(t)}{\partial T_2(t)} &= \frac{\beta F(t)}{N(t)} \ h_2 \bar{N}_2 - \frac{\widetilde{\sigma} \ \widetilde{R}(t)}{(\widetilde{\sigma} - T_2(t))^2} = 0 \end{aligned} \tag{13}$$

The profit satisfying the first-order conditions is positive; $\pi(t) = \frac{\widetilde{R}(t)\ T_2^2(t)}{(\widetilde{\sigma} - T_2(t))^2} > 0$.

It should be noted that profit is zero if monopoly is replaced by perfectly competitive labor market. As group 1 receives all the profit, we have:

$$\pi_1(t) = \frac{\pi(t)}{\bar{N}_1} \tag{14}$$

Demand and supply of goods

As the output of the firm is equal to the depreciation of capital stock and the net savings, we have

$$C(t) + S(t) - K(t) + \delta_k K(t) = F(t) \tag{15}$$

where $S(t) = s_1(t)\bar{N}_1 + s_2(t)\bar{N}_2$ and $C_t = c_1(t)\ \bar{N}_1 + c_2(t)\ \bar{N}_2$.

The national wealth is owned privately

The physical capital is fully employed and is owned privately:

$$K(t) = \bar{k}_1(t)\ \bar{N}_1 + \bar{k}_2(t)\ \bar{N}_2 \tag{16}$$

We completed the model. The model is structurally a more generalized version of some well-known models in economics. For instance, our model is an extended version of the model presented in Solow (1956) due to having a non-homogeneous population. Similarly, our model becomes a Walrasian general equilibrium model under the assumptions of a fixed level of household wealth, no depreciation in physical capital, and perfect competition in all markets. It is the first model, as far as I am aware of, to introduce monopsony into neoclassical growth theory.

3 The dynamics and the properties of the model

As getting an explicit analytical solution for a nonlinear dynamic system of equations is difficult, a numerical method is utilized to trace the dynamic properties of the model economy. The lemma given below indicates that the dimension of the dynamic system is the same as the number of groups and provides a computational procedure to solve the system of equations for each endogenous variable for each time period. First, we introduce a new variable $z(t)$ as follows.

$$z(t) \equiv \frac{r(t)+\delta_k}{w_1(t)}$$

Lemma: The motion of the economic system is determined by 2 differential equations with $z(t)$ and $k_2(t)$ as the variables:

$$\begin{aligned} \dot{z}(t) &= \Lambda_1(z(t), \bar{k}_2(t)) \\ \dot{\bar{k}}_2(t) &= \Lambda_2(z(t), \bar{k}_2(t)) \end{aligned} \tag{17}$$

where $\Lambda_j(t)$ are unique functions of $z(t)$ and $\bar{k}_2(t)$. At any point in time, the other variables are unique functions of these two variables. Each variable is associated with an equation, Table 1.[2]

[2] See Appendix A for the proof of lemma.

Table 1: Variable-Equation Pairing

$r(t)$	(A.2)	$w_1(t)$	(A.3)
$T_2(t)$	(A.8)	$\bar{T}_2(t)$	(5)
$w_2(t)$	(A.9)	$\bar{k}_1(t)$	(A.15)
$\pi(t)$	(A.6)	$\bar{y}_1(t)$	(A.11)
$\bar{T}_1(t),\ c_1(t)$ and $s_1(t)$	(A.7)	$T_1(t)$	(5)
$\bar{y}_2(t)$	(A.10)	$c_2(t)$ and $s_2(t)$	(A.7)
$N(t)$	(1)	$K(t)$	(A.1)
$F(t)$	(A.5)	$U_j(t)$	by the definitions

The Lemma provides a computational procedure for following the movement of the economy. We specify parameter values in Table 2.

Table 2: The Chosen Values of Parameters

$A = 1.3$	$\alpha = 0.34$	$\overline{N}_1 = 20$	$\overline{N}_2 = 10$	$h_1 = 2.2$
$h_2 = 2$	$T_0 = 24$	$\delta_k = 0.05$	$\lambda_{10} = 0.8$	$\xi_{10} = 0.12$
$\sigma_{10} = 0.14$	$\lambda_{20} = 0.8$	$\xi_{20} = 0.1$	$\sigma_{20} = 0.24$	

The parameter values are not especially referred to a real economy. The discriminatory population and discriminated population are, respectively, 20 and 10. The total factor productivity is chosen as 1.3. We specify the values of the parameter α in the Cobb-Douglas production approximately equal to 0.34 by following Miles & Scott (2005) and Abel et al. (2007). By following the literature of economic growth, depreciation rate of physical capital stock is chosen as 0.05.[3] As our comparative dynamic analyses examine the impacts of changes in the specified parameter values on the transitional dynamics of the model, the chosen values of parameters do not matter so much. We specify the following initial conditions:

$$z(0) = 0.027, \quad \bar{k}_2(0) = 168$$

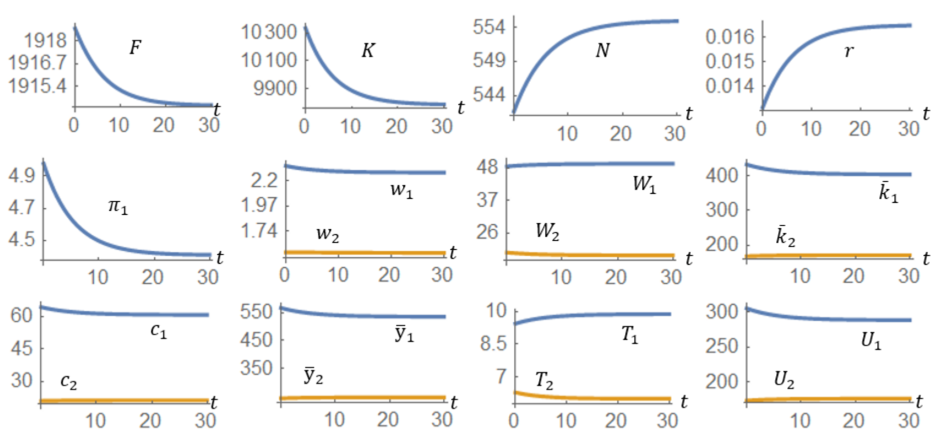

Figure 1: The Transitional dynamics of the model

[3] Nadiri & Prucha (1996) estimates the depreciation rate of capital as 0.059. For different empirical results, see Fraumeni (1997) and Hall (2007).

The paths of the variables are plotted in Figure 1. From the initial state, the national output and wealth/capital fall over time. The national labor supply rises over time. The interest rate rises. The wage rates and wage incomes change slightly.

The existence of an equilibrium point is guaranteed as it is confirmed that all the variables become stationary in the long term. Sensitivity analyses with different initial conditions lead to the same equilibrium point. We list the equilibrium values in Table 3.

Table 3: Initial Steady-state Values

$Y = 1,914.3$	$K = 9,784.9$	$N = 555.1$	$r = 0.017$	$\pi_1 = 4.41$	$w_1 = 2.28$
$w_2 = 1.54$	$W_1 = 49.1$	$W_2 = 18.52$	$\bar{k}_1 = 403.8$	$\bar{k}_2 = 170.7$	$c_1 = 60.6$
$c_2 = 21.3$	$T_1 = 9.89$	$T_2 = 6.01$	$U_1 = 288.3$	$U_2 = 175.8$	

We also conduct sensitivity analyses with wide ranges of values of the variables z and $\bar{k}_2$. It is concluded that the system has a unique stable equilibrium. It is straightforward to calculate the two eigenvalues as $\{-0.17, -0.15\}$ for z and $\bar{k}_2$, respectively. Since the eigenvalues are real and negative, the unique equilibrium is stable. This guarantees the validity of the following comparative dynamic analyses.

4 Comparative dynamic analysis

We are now concerned about how the economic system described above reacts to different exogenous changes. By using the computational routine provided by the Lemma, we can quantify the effects of a change in any of the parameters on all the endogenous variables during the transition processes as well as in the new stationary steady-state. We introduce a variable $\bar{\Delta}x(t)$ to express the percentage change rate in the variable $x(t)$ due to a given change in a parameter value.

4.1 The total factor productivity is increased

We first study what happens to the economic system if the total factor productivity, A, is increased from 1.3 to 1.35. The simulation result is plotted in Figure 2.

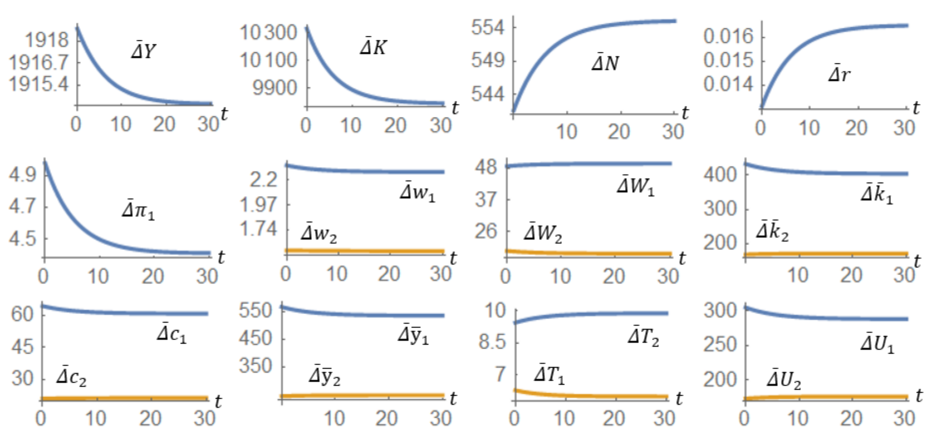

Figure 2: Positive Total Factor Productivity Shock

The higher level of productivity improves the national output and national wealth. The work hours of the two groups and total labor supply are increased initially but affected slightly in the long term. The interest rate increased initially but is slightly affected in the long term. The wage rates and wage incomes of the two groups are increased. The profit is increased. Each household has more wealth, consumes more goods, and gets a higher level of utility, compared to the initial steady-state. We see that the two groups benefit differently. The discriminated group benefits slightly more in comparison to the discriminatory group. The discriminated works for more hours and at slightly enhanced wage rate, while the discriminatory works for more hours but its wage rate is greatly enhanced. The difference in the wage rate changes is due to the monopsony. If there was no monopsony; the two groups would have enjoyed the same rise in the wage rates.

4.2 The discriminated group's human capital is enhanced

We now analyze what happens to the economic system if the discriminated group's human capital, h_2, is increased from 2 to 2.1. The simulation result is plotted in Figure 3. The wage rate of the discriminated group falls initially but changes slightly in the long run. The wage rate of the discriminatory group is slightly affected. The wage income of each group is increased. The discriminated household works more hours, while the discriminatory household works almost the same hours. The discriminatory household's profit receipts increase. The national income, national capital and national labor supply are augmented.

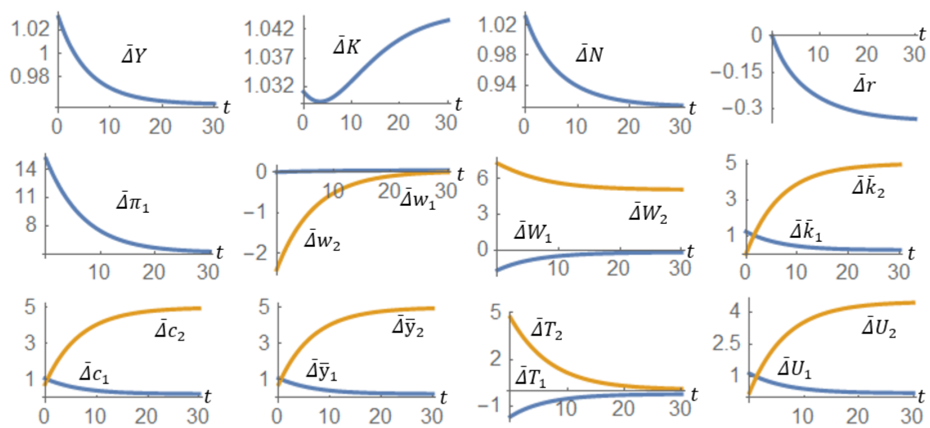

Figure 3: Positive Human Capital Shock to the Discriminated Group

The interest rate falls. Each household consumes more, has more wealth, and enjoys a higher utility level. The gaps in potential disposable income, wage income and wealth between the two groups shrink. The discriminated group benefits more in terms of consumption, wealth and utility than the discriminatory group.

4.3 The discriminatory household's human capital is enhanced

We now analyze what happens to the economic system if the discriminatory household's human capital, h_1, is increased from 2.2 to 2.3. The simulation result is plotted in Figure 4. The wage rate of each group slightly falls. The wage income of the discriminated is slightly affected. The wage income of the discriminatory is increased. The discriminated works fewer hours, while the discriminatory works more hours. The discriminatory household's profit is slightly reduced. The national income, national capital and national labor supply are

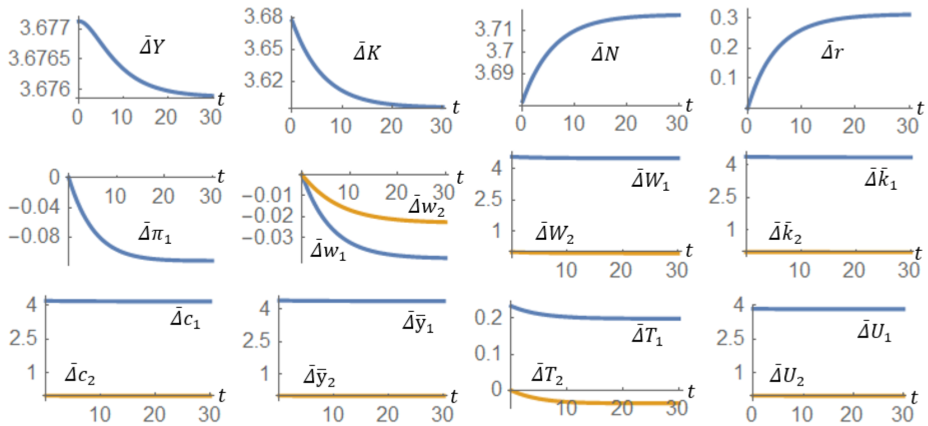

Figure 4: Positive Human Capital Shock to the Discriminatory Group

augmented. The interest rate is higher. The discriminatory household consumes more, has more wealth, and enjoys a higher utility level. The discriminated household's consumption, wealth and utility are slightly affected. The gaps in potential disposable income, wage income and wealth between the two groups are enlarged.

4.4 The discriminated population is enhanced

We now study what happens to the economic system if the discriminated population, $\bar{N}_2$, is increased from 10 to 11. The simulation result is plotted in Figure 5. The wage rate of each group slightly rises. The wage income of the discriminatory group is slightly affected. The wage income of the discriminatory household is decreased. The wage income of the discriminatory household is increased. The discriminated household works more

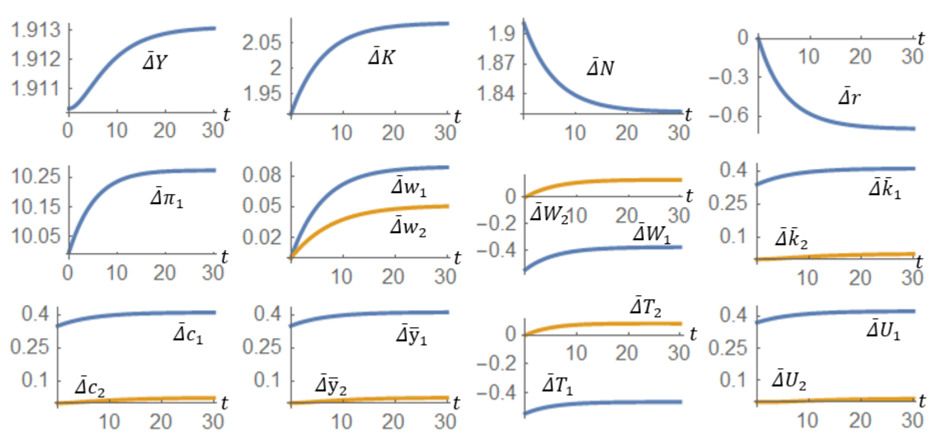

Figure 5: Positive Population Shock to the Discriminated Group

hours, while the discriminatory household works fewer hours. The discriminatory household receives more profit. The national income, national capital and national labor supply are augmented. The rate of interest is decreased. The discriminatory household consumes more, has more wealth, and enjoys a higher utility level mainly due to the increased profit receipts. The discriminated household's consumption, wealth and utility are slightly affected. The gaps in potential disposable income, wage income and wealth between the two groups are enlarged due to the increase in the discriminated population.

4.5 The discriminated group enhance the propensity to save

We examine what happens to the economic system if the discriminated household increases its propensity to save, λ_{20}, from 0.8 to 0.81. The simulation result is plotted in Figure 6. The wage rate of the discriminated group falls initially but rises in the long term. The wage income of the discriminated household is enhanced. The wage rate of the discriminatory household is increased slightly, and the wage income is enhanced in the long term. Both households' wealth is increased, but the effect is negligible for the discrimina-

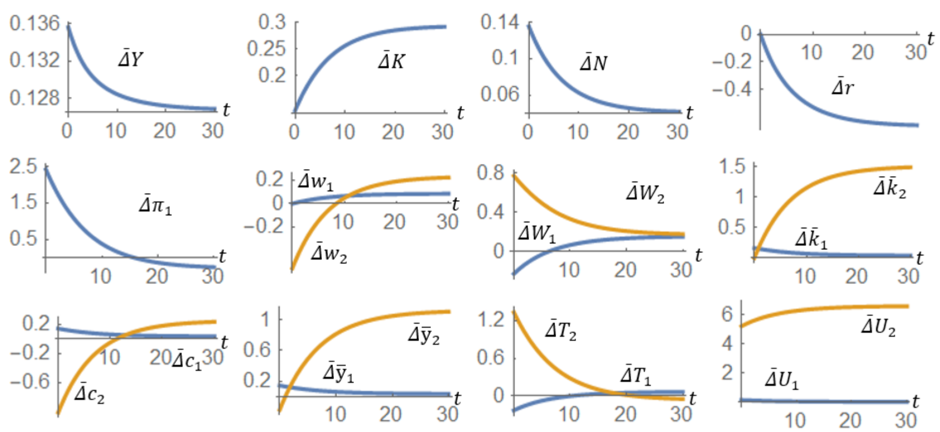

Figure 6: Positive Shock to the Saving Propensity of the Discriminated Group

tory household. The national output and national wealth are increased. The national labor supply is slightly affected. The rate of interest falls. In the long term, the discriminated household consumes more, has more wealth, and has higher utility level. It should be noted that the discriminated household's enhanced saving propensity reduces the discriminatory household's profit.

4.6 The discriminated group enhances the propensity to use leisure time

We examine what happens to the economic system if the discriminated household increases its propensity to use leisure time, σ_{20}, from 0.26 to 0.27. The simulation result is plotted in Figure 7. The wage rate of the discriminated group rises but its wage income is reduced. The wage rate of the discriminatory household is increased slightly, and its wage income is enhanced. The wealth of both households are reduced. The national output, national wealth and national labor supply are reduced. The interest rate rises. In the long term, the discriminated household consumes less, has less wealth, but has a higher utility level. The discriminatory household works more hours, has less profit, less wealth,

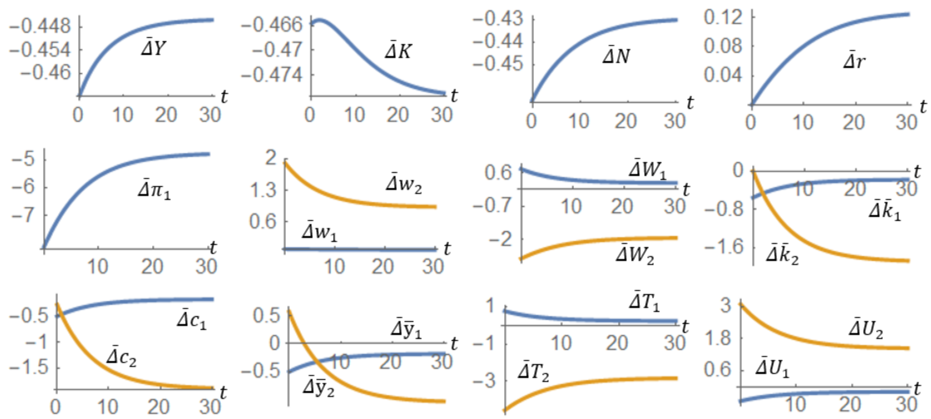

Figure 7: Positive Shock to the Leisure Time Propensity of the Discriminated Group

lower consumption level and lower utility level. We thus conclude that if the discriminated household has higher propensity to stay at home, the discriminatory household loses.

5 Comparing with perfect competition

This section compares the dynamics of the model with monopsony and the model with perfect competition. When the system is perfectly competitive, firm takes price as given and equilibrium between demand and supply determines the price.[4] A main difference is that the profit is zero in perfect competition, i.e. $\pi_j(t) = 0$. We plot the movement of the two systems under the same parameter values in Table 3. The results are plotted in Figure 8, except for the profits as firm gets zero profit in the perfectly competitive economy.

In the short term, the discriminatory household has more wealth in monopsony than in perfect competition, while this is opposite for the discriminated household. The net results of the two groups' wealth changes lead to a reduction in the national capital stock in perfect competition. The two types of households work more hours in perfect competition than in monopsony both in the short term as well as in the long term.

In the long term, we see that in the economy with monopsony the national output, total labor supply and national wealth are lower than in the perfectly competitive economy. In monopsony economy, however, the interest rate is higher. But two groups' wage incomes become lower. Workers work fewer hours and consume less. They have lower utility levels. In summary, it is evident that the economy performs better in the perfectly competitive economy, and all the people have higher welfare (at least in the long term).

It should be noted that in the short-term, group 1 (which receives the profit from monopsony or conducts discrimination) loses from perfect competition. We see that it is important to develop a genuine dynamic model for explaining the dynamic processes with different institutions. In a general equilibrium model without wealth accumulation, we cannot distinguish between the long-term effects and the short-run effects. Conclusions from a traditional general equilibrium theory might be misleading in the sense that we may fail to predict the

[4] Appendix B provides the growth model when all markets are perfectly competitive and includes a computational program to plot the movement of the competitive model.

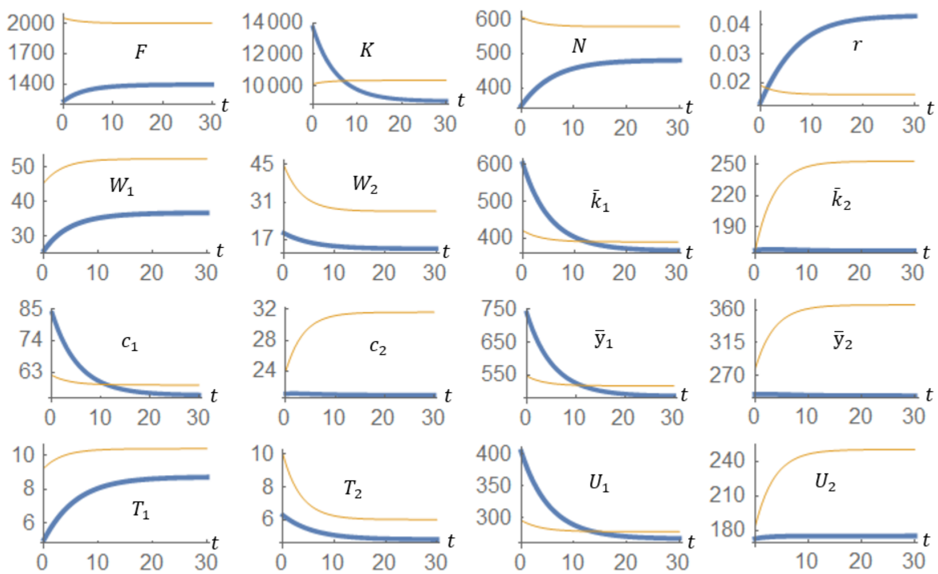

Figure 8: Comparing the Transitional Dynamics of the Two Economic Systems
Note: Thick blue lines show the monopsony and thin yellow lines show the perfect competition.

long-term harmful consequences of monopsony not only for the discriminated but also for the discriminatory.

6 Concluding remarks

This study introduced monopsony to the neoclassical growth theory with Zhang (2013, 2017)'s concept of disposable income and utility function. The modelling of monopsony is based on the traditional monopsony theory. The model endogenously determines the profit of the firm, which is equally distributed among the discriminatory population. We built the model and then found a computational procedure to plot the movement of the economic system. We conducted comparative dynamic analyses in some parameters. We also compared the economic performances of the traditional model with perfect competition and the model augmented with monopsony. We concluded that the monopsony in labor market decreases national output, national wealth and utility level in comparison to the perfect competition. This result has important political implications. Since monopsony harms all the people in the society in the long term, it would be desirable for the government to maintain a more competitive and fairer environment so that different people can live in harmony in the long term.

It should be noted that our conclusions are made under the assumption that the profits due to monopsony are distributed to the discriminatory. In reality, profits might be invested in innovation or re-distributed through taxation. The model can be extended and generalized in many directions. As it is based on some simple cases of well-developed theories and each theory has its own complicated literature, it is not difficult to conceptually and analytically extend and generalize our model according to the literature. For instance, gender discrimination is a key issue in the theory of monopsony. It is straightforward to expand our model to multiple sectors and multiple groups (Zhang, 2013). How to formulate proper tax policies and how to re-distribute profits is a challenging question in an economy with multiple types of market structures. Moreover, the literature of monopsony power is often based on search theory (e.g. Black, 1995; Bowlus, 1997). There are factors, such as mobility costs, job differentiation, firm locations, wage settings, and search frictions, which may play a role in sustaining monopoly power. Search theory approach may further enrich our approach to monopsony explored in this study.

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Appendices

Appendix A: Solving the Consumer Problem

By (13), we obtain

$$z \equiv \frac{r+\delta_k}{w_1} = \frac{\bar{\beta} N}{K} \tag{A.1}$$

where $\bar{\beta} \equiv \alpha/\beta$. Insert (A.1) in (13)

$$r(z) = \alpha A \left(\frac{z}{\bar{\beta}}\right)^{\beta} - \delta_k \tag{A.2}$$

From (A.2) and (A.1)

$$w_1 = \frac{r+\delta_k}{z} \tag{A.3}$$

By (13), we have

$$\alpha F + \frac{\beta F}{N} h_1 T_1 \bar{N}_1 + \frac{\beta F}{N} h_2 T_2 \bar{N}_2 = R_\delta K + w_1 h_1 T_1 \bar{N}_1 + \frac{\widetilde{\sigma}\ T_2\ \widetilde{R}}{(\widetilde{\sigma} - T_2(t))^2} \tag{A.4}$$

By (1) and (9), (A.4) becomes

$$F = R_\delta K + w_1 h_1 T_1 \bar{N}_1 + \frac{\widetilde{\sigma} T_2 \widetilde{R}}{(\widetilde{\sigma} - T_2(t))^2} \tag{A.5}$$

By (12) and (A.5), we have

$$\pi = \frac{\widetilde{R}\ T_2^2}{\widetilde{\sigma} - T_2^2} > 0 \tag{A.6}$$

By (A.1) and (9), we have

$$F = fN, \quad f \equiv A \left(\frac{\bar{\beta}}{z} \right)^{\alpha} \tag{A.7}$$

By (A.7) and the last equation in (13) we have

$$T_2 = \widetilde{\sigma} - \left(\frac{\widetilde{\sigma} \ \sigma_2 \ R \ \bar{k}_2}{\beta \ f \ h_2} \right)^{(1/2)} \tag{A.8}$$

We have group 2's wage rate as

$$w_2 = \frac{\sigma_2 \ R \ \bar{k}_2}{(\widetilde{\sigma} - T_2) \ h_2} \tag{A.9}$$

By (6) and (A.9) we have

$$\bar{y}_2 = R \ \bar{k}_2 + \frac{\sigma_2 \ T_0 \ R \ \bar{k}_2}{\widetilde{\sigma} - T_2} \tag{A.10}$$

By (A.6) and (6) we have

$$\bar{y}_1 = R \ \bar{k}_1 + h_1 \ T_0 \ w_1 + \frac{\widetilde{R} \ T_2^2}{(\widetilde{\sigma} - T_2)^2 \ \bar{N}_1} \tag{A.11}$$

By (15) and (A.1), we have

$$\frac{\bar{\beta} N}{z} = \bar{k}_1 \ \bar{N}_1 + \bar{k}_2 \ \bar{N}_2 \tag{A.12}$$

Insert (1) in (A.12)

$$h_1 \ T_1 \ \bar{N}_1 + h_2 \ T_2 \ \bar{N}_2 = \frac{\bar{k}_1 \ z \ \bar{N}_1}{\bar{\beta}} + \frac{\bar{k}_2 \ z \ \bar{N}_2}{\bar{\beta}} \tag{A.13}$$

From (5) and (7), we have

$$T_1 = (1 - \sigma_1) \ T_0 - \frac{\sigma_1 \ R \ \bar{k}_1}{h_1 \ w_1} - \frac{\sigma_1 \ \widetilde{R} \ T_2^2}{(\widetilde{\sigma} - T_2)^2 \ h_1 \ w_1 \bar{N}_1} \tag{A.14}$$

where we also use (A.11). Insert (A.14) in (A.13)

$$\bar{k}_1 = \varphi(z, \bar{k}_2) \equiv \left((1 - \sigma_1) \ h_1 \ \bar{N}_1 \ T_0 - \frac{\sigma_1 \ \widetilde{R} \ T_2^2}{(\widetilde{\sigma} - T_2)^2 \ w_1} + h_2 \ T_2 \ \bar{N}_2 - \frac{\bar{k}_2 \ z \ \bar{N}_2}{\bar{\beta}} \right) \ \bar{f} \tag{A.15}$$

where

$$\bar{f}(z, \bar{k}_2) \equiv \left(\frac{z}{\bar{\beta}} + \frac{\sigma_1 R}{w_1} \right)^{-1} \frac{1}{\bar{N}_1}$$

It is straightforward to confirm that all the variables can be expressed as functions of z and $\bar{k}_2$ by the procedure summarized in Table 1. From this procedure and (8), we have

$$\dot{\bar{k}}_1 = \Lambda_0(z, \bar{k}_2) \equiv \lambda_1 \ \bar{y}_1 - \varphi \tag{A.16}$$

$$\dot{\bar{k}}_2 = \Lambda_2(z, \bar{k}_2) \equiv \lambda_2 \ \bar{y}_2 - \bar{k}_2 \tag{A.17}$$

Taking derivative of equation (A.15) with respect to t implies

$$\dot{\bar{k}}_1 = \frac{\partial \varphi}{\partial z}\dot{z} + \Lambda_2 \frac{\partial \varphi}{\partial \bar{k}_2} \tag{A.18}$$

where we use (A.17). Equal (A.18) and (A.16)

$$\dot{z} = \Lambda_1(z, \bar{k}_2) \equiv \left(\Lambda_0 - \Lambda_2 \frac{\partial \varphi}{\partial \bar{k}_2}\right)\left(\frac{\partial \varphi}{\partial z}\right)^{-1} \tag{A.19}$$

We thus confirmed the Lemma.

Appendix B: The model dynamics when all markets are perfectly competitive

When all markets are perfectly competitive, firm takes group 2's wage rate as given as well. The Profit of firm is zero. Workers are fairly paid so that $w = w_1 = w_2$. We still have (1-5), (8), and (9). The rest of the economic system is described as follows:

$$h_j \ \bar{T}_j(t) \ w_j(t) + c_j(t) + s_j(t) = \bar{y}_j(t) \equiv R(t) \ \bar{k}_j(t) + h_j \ T_0 \ w_t \tag{6'}$$

$$h_j \ \bar{T}_j(t) \ w(t) = \sigma_j \ \bar{y}_j(t), \quad c_j(t) = \xi_j \ \bar{y}_j(t), \quad s_j(t) = \lambda_j \ \bar{y}_j(t) \tag{7'}$$

$$\begin{aligned} \frac{\partial \pi(t)}{\partial K(t)} &= \frac{\alpha \ F(t)}{K(t)} - R_\delta(t) = 0 \\ \frac{\partial \pi(t)}{\partial N(t)} &= \frac{\beta \ F(t)}{N(t)} - w(t) = 0 \end{aligned} \tag{13'}$$

An equation with number $'$ in the appendix corresponds to the equation with the same number in Section 2. With the same utility function and (15), we have the model with perfect competition in all the markets. Similar to Appendix A, we have (A.1-A.3). Corresponding to (A.11) and (A.13), we have

$$\bar{y}_j = R \ \bar{k}_j + h_j \ T_0 \ w \tag{A.11'}$$

$$h_1 \ T_1 \ \bar{N}_1 \ + h_2 \ T_2 \ \bar{N}_2 = \frac{\bar{k}_1 \ z \ \bar{N}_1}{\bar{\beta}} + \frac{\bar{k}_2 \ z \ \bar{N}_2}{\bar{\beta}} \tag{A.13'}$$

From (6') and (7'), we have

$$T_j = (1 - \sigma_j) \ T_0 - \frac{\sigma_j \ R \ \bar{k}_j}{h_j \ w}$$

Insert the above equations in (A.13')

$$\bar{k}_1 = \left(h - \frac{\sigma_2 \ \bar{N} \ R \ \bar{k}_2}{w} - \frac{\bar{k}_2 \ z \ \bar{N}_2}{\bar{\beta}}\right)\left(\frac{z}{\bar{\beta}} + \frac{\sigma_1 \ R}{w}\right)^{-1} \frac{1}{\bar{N}_1}$$

where

$$h \ \equiv \ (1 - \sigma_1) \ h_1 \bar{N}_1 \ T_0 + (1 - \sigma_2) \ h_2 \ \bar{N}_2 \ T_0$$

Similar to the Lemma, we can easily find a computational procedure to simulate the model.