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Kiel Working Papers

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Whodunnit?

**Changes in the Relative Demand
for Unskilled and Skilled Labor***

by Axel Schimmelpfennig



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Whodunnit?
Changes in the Relative Demand
for Unskilled and Skilled Labor*

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Abstract

The secular shift in labor demand from unskilled to skilled labor is explained within a model that is solved numerically. There are three branches producing a basic good, a differentiated luxury good, and an intermediate service. Production is more skill-intensive in the luxury good and the service branch. Consumption expenditure shifts towards the luxury good with rising income. In this setting, both unskilled-specific and neutral technical change lead to a rise in the relative wage of the skilled. Increasing unemployment results only for a restrictive assumption about labor market rigidities.

*Keywords: Skill-biased technical change, wages,
unemployment*

JEL Classification: E24, J21, J31

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1 Introduction

Across OECD-countries, unskilled labor has lost ground relative to skilled labor. In countries characterized by flexible labor markets such as the United States, unskilled labor has suffered losses in relative and real wages. In countries characterized by rigid labor markets such as Germany, unskilled labor has suffered from increased unemployment. This secular trend has been extensively discussed in the literature on "trade and wages" and "skill-biased technical change". However, no satisfactory explanation for the change in relative labor demand has been given so far. Most theoretical explanations have been empirically rejected. The empirical finding Skill-biased technical change is substantiated with little theoretical work: skill-biased technical change is nothing but a residual, a name for what we do not understand.

In this paper I suggest a general equilibrium model to analyze the impact of different types of technical change for flexible and rigid labor markets; the model is solved numerically. The model differs from the existing literature in that preferences shift with rising income from an unskilled-intensive basic good to a skilled-intensive differentiated luxury good. Through this mechanism, even neutral technical change can lead to changes in the skill composition. The model also contains an intermediate service to allow for the observed service intensification in industrialized countries to drive the shift in relative labor demand (cf. Klodt et al. 1997). With this model, I attempt to clarify some conceptions and misconceptions about the nature of skill-biased technical change.

The main results are: In the flexible labor market case, unskilled-specific technical change and neutral technical change reproduce the labor market development in countries such as the United States. In the rigid labor market case, unskilled-specific technical change and neutral technical change reproduce the

labor market development in countries such as Germany only under the additional, restrictive assumption of a constant relative wage. Therefore, technical change by itself cannot be held responsible for the increase in unemployment. Instead, labor market rigidities that hinder adjustment after a technological shock are at the root of the unemployment problem.

The remaining paper is organized as follows. Section 2 reviews the related literature. Section 3 presents the model. Section 4 discusses the impact of different types of technical change. Section 5 summarizes the main results and sketches avenues for future research.

2 Setting the Scene

The discussion about the impact of technical change on employment dates back to the writing of Ricardo (1821: chapter XXXI). However, as e.g. Blattner (1996: 212) points out, technical change by itself does not cause unemployment. Technical change can shift the production possibility frontier, or technical change can alter the optimal factor proportion in production.¹ But in order for technical change to be associated with unemployment, it must coincide with labor market rigidities² that hinder adjustment.

In the recent empirical and theoretical literature, the observed shift in relative labor demand in favor of skilled workers is attributed to a skill-biased technical change. As Rodrik (1998: 6) nicely summarizes: "In particular, the fact that skill upgrading has taken place *within* industries (as measured by increasing ratios of non-production to production workers, for example) has been read as evidence

¹ This is another point often neglected in the literature and raised by Blattner: If the skill-bias is not too strong, unskilled workers may still benefit due to the expansion in demand that results from increased income of the skilled. See also Gundlach and Nunnenkamp (1997).

² For a discussion of labor market rigidities in the European context see e.g. Siebert (1997).

in favor of the technology hypothesis and against the trade hypothesis." The shift towards more skilled workers is observed within every sector of the economy. Therefore, sectoral structural change, e.g. caused by trade, cannot be a dominant driving force. Instead, skill-biased technical change is identified as the factor driving relative labor demand (e.g. Katz and Murphy 1992, Berman et al 1994, or Johnson 1997).

The use of computers by workers has been taken as a proxy for technical change in several empirical studies.³ For the United States, Krueger (1993: 33) : "workers who use computers on their job earn 10 to 15 percent higher wages." Autor et al. (1997) find skill upgrading most strongest in industries with high computer use per employee also for the United States. Haskel and Heden (1998) confirm these results for the United Kingdom. However, with data for Germany, DiNardo and Pischke (1997) show that computer use by itself does not determine wages. The authors find computers to be a proxy variable for some unobserved skill – just as the use of pencils.

These studies implicitly view technical change as skilled-specific: Computers increase the productivity of skilled workers. Considering the concepts of neutrality suggested in growth theory (e.g. Barro and Sala-i-Martin 1995) this assumption appears somewhat surprising. If computers were to increase the productivity of skilled workers, they should be referred to as skilled-specific technical change, which leads to a fall in the skilled wage share.

Insightful evidence comes from a study for the United States by Doms et al. (1997). In a cross-sectional analysis they find innovative firms having a higher share of skilled workers. However, in a panel analysis, they fail to find an

³ Of interest for the profession may also be the study by Hamermesh and Oster (1998) on the impact of computers on scholarly productivity.

increase in the share of skilled workers after firms have implemented an innovation. Kölling (1998) attempts to identify the presence skill-biased technical change at the firm level in West-Germany. His regression analysis could not provide support for skill-biased technical change as a dominant factor influencing a firm's skill composition. Therefore, changes in the skill-composition must be accounted for by shifts across firms.

The majority of studies are based on the implicit assumptions that sectors produce a single homogeneous good. Even at a very disaggregate level, this assumption is a poor approximation of reality. A more realistic assumption is that of sectors producing a set of heterogeneous goods which are close substitutes in consumption.

There is circumstantial evidence that consumers shift expenditure towards higher quality varieties as income rises.⁴ Pischner (1999) shows that the demand for personal services is an increasing function of income in Germany. Within personal services, there seems to be a tendency towards more sophisticated services. Heien and Wessells (1990) find that a large variety of basic food with the exception of meat is a decreasing function of expenditure in the United States. Also with data for the United States, Park et al. (1996) show that subsistence expenditure on different food groups vary significantly with income. Households with higher income have a higher subsistence level for 'food away from home' and beef, while households with lower income have a higher subsistence level for bread or chicken.

⁴ Adam Smith (1776: Book I, Chapter XI, Part II) has already touched upon this subject: „The desire of food is limited in every man by the narrow capacity or the human stomach; but the desire of the conveniences and ornaments of building, dress, equipage, and household furniture, seems to have no limit or certain boundary“.

Moreover, goods demand can be assumed to shift towards more differentiated and more skill-intensive goods within sectors, as income rises. At low income levels, individuals satisfy their basic needs by consuming mostly a basic variety. As income increases, individuals turn to other varieties that also satisfy non-basic needs.⁵ Consider the example of bicycles. At a low income level, the individual consumes a basic bicycle that has neither gears, shock-absorbers, nor is it particularly light-weight. At a high income level, the individual consumes a variety of sophisticated bicycles. He has a mountain bike with 21 gears and shock-absorbers. He has a feather-weight road-bike. And he has a city-bike that takes him to work. In addition, the bikes are equipped with gadgets like a speedometer or even a GPS. The development as well as the production of these bicycles is skill-intensive.

In a companion paper I show that a significant share of the shift in relative labor demand in Germany occurs between unskilled-intensive physical production and skilled-intensive intermediate services (Schimmelpfennig 1998). This corresponds to an expenditure shift towards more skill-intensive goods. For an individual, the upgrading of consumed varieties must not necessarily occur across all groups of goods. In most cases, it will be concentrated on some goods according to his preferences. Empirically this should lead to an increased dispersion of household expenditure for narrowly defined group of goods with rising income. Hildenbrand (1994: chapter 3) presents estimation results for the United Kingdom that are in accordance with this hypothesis.

Given this framework, technical change can affect relative labor demand in two ways: (i) directly from the supply side through changes in labor productivity; and (ii) indirectly from the demand side through changes in consumption

⁵ This assumption corresponds to Maslov's hierarchy of needs

expenditure towards more skill-intensive varieties of goods. Unskilled-specific technical change leads to a shift away from unskilled labor from the supply side and, through the rise in income, to an additional shift from the demand side. Neutral technical change merely only leads to a shift from the demand side. Skilled-specific technical change leads to a shift from the supply side away from skilled labor that is countered by a shift from the demand side towards skilled labor.

3 The Model

The upskilling observed across industrialized countries is explained by a model that considers unskilled-saving technical change, skilled-saving technical change, neutral technical change, and changes in the productivity of an intermediate service. These shocks are analyzed for a flexible labor market case and a rigid labor market case. The objective is to see which factor leads to changes in the skill composition and the wage differential across skill groups that correspond to the ones observed in countries such as the United States and Germany.

Individuals supply either unskilled or skilled labor. They consume a basic good and varieties of a luxury good (Figure A1). By way of the preference function, demand shifts from the basic good to the luxury good with rising income. Firms produce the basic good, varieties of the luxury good, and varieties of an intermediate service for the production of the luxury goods (Figure A2). The basic good and the intermediate service are produced using unskilled and skilled labor. The luxury good is produced using unskilled and skilled labor, and in addition the intermediate services.

3.1 Individual Goods Demand

Goods demand results from individual utility maximization with respect to the consumption of a basic and a differentiated luxury goods. Individuals increase the expenditure share of the differentiated good with rising disposable income. The Stone-Geary (SG) or Klein-Rubin preference function (Klein and Rubin 1947-1948, Samuelson 1947-1948) incorporates the assumption of changing expenditure shares by specifying a minimum quantity β_j of each good to be consumed. This minimum quantity can be thought of as a subsistence level.⁶ Letting $Q_{z,1}$ denote the quantities of the basic good and $Q_{z,2}$ the aggregate quantity of the differentiated good, individual z 's preferences are given by

$$U_z = (1 - \alpha) \log(Q_{z,1} - \beta_1) + \alpha \log(Q_{z,2} - \beta_2) \quad (1)$$

where $0 < \alpha < 1$ and $Q_{z,j} - \beta_j > 0$ for $j = 1, 2$

From equation (1) it can be seen that the SG preference function is a generalization of a Cobb-Douglas (CD) preference function where only excess quantities $Q_{z,j} - \beta_j$ of any good j generate a positive utility. SG indifference curves are therefore identical to CD indifference curve except for a shift in origin from $(0,0)$ in the CD-case to (β_1, β_2) in the SG-case (Figure A3). The shift in origin leads to the SG being a non-homothetic preference function: As disposable income varies, the expenditure shares of different goods change.⁷

⁶ There are two interpretations of the minimum quantity (cf. Pollak and Wales 1992: 14). First, the minimum quantity can be a physiological minimum, like a certain amount of food, clothing, or shelter. Second, the minimum quantity can be a psychological minimum that derives, for example, from habit formation. Consumption in the present period is not supposed to fall below last period's consumption of a good i . For the model at hand, the first interpretation is chosen.

⁷ Other implications of the shift in origin are discussed in Pollak and Wales (1992: pp. 7).

The differentiated good $Q_{z,2}$ is a composite of all n available varieties $q_{z,2,i}$ (love of variety). The different varieties are aggregated by means of a CES-function with parameter of differentiation ρ (2). This type of aggregation implies that consumers have identical preferences among the varieties of the differentiated goods; the elasticity of substitution between any two varieties is identical. The nested preference function implies that the basic good and the varieties of the luxury good are weakly separable.

$$Q_{z,2} = \left[\sum_{i=1}^n q_{z,2,i}^\rho \right]^{\frac{1}{\rho}} \quad (2)$$

An individual spends his disposable income E_z on the basic good and the luxury good. There is no saving, since the model is static. Disposable income depends on an individual's employment status and skill level. Unemployed individuals receive a non-wage income as a percentage of the wage rate for their respective skill group rw_k , where r is the replacement ratio. The non-wage income is financed through a general tax τ_B on the wage of the employed. The budget constraint is given by

$$E_z = p_1 Q_{z,1} + \sum_{i=1}^n p_{2,i} q_{z,2,i} \quad (3)$$

where p is the price of the respective good.

Individuals maximize their preference function (1) subject to the budget constraint (3).⁸ Letting σ denote the elasticity of substitution between any two varieties, demand for one variety of the luxury good is given by

⁸ Derivations are presented in Appendix 2.

$$q_{z,2,j} = \frac{p_{2,j}^{-\sigma}}{\sum_{i=1}^n p_{2,i}^{1-\sigma}} (E_z - p_1 Q_{z,1}) \quad (4)$$

The price index for the aggregate luxury good is

$$P_2 = \left(\sum_{i=1}^n p_{2,i}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \quad (5)$$

Demand for the basic good and for the aggregate luxury good is given by the linear expenditure system (LES) of equations (6) and (7).⁹

$$Q_{z,1} = \beta_1 + \frac{1-\alpha}{p_1} [E_z - p_1 \beta_1 - P_2 \beta_2] \quad (6)$$

$$Q_{z,2} = \beta_2 + \frac{\alpha}{P_2} [E_z - p_1 \beta_1 - P_2 \beta_2] \quad (7)$$

First, individuals purchase the subsistence quantities of each good. The remaining disposable income is used to purchase more of each good according to the preference parameter α .

The expenditure share of the aggregate luxury good is

$$s_{z,2} = \frac{P_2 \beta_2}{E_z} + \alpha \left[1 - \frac{p_1 \beta_1 + P_2 \beta_2}{E_z} \right] \quad (8)$$

⁹ Multiplying the demand functions by the price of the respective good shows that expenditure for a good is a linear function of its own price and the prices of all other goods. Because the demand system is linear in prices, it has been widely used in empirical studies of demand at the macro and micro level. See, e.g. Hansen (1993: pp 286) or Missong and Stryck (1998).

And the derivative of the expenditure share with respect to expenditure is

$$\frac{\partial s_{z,2}}{\partial E_z} = \alpha \frac{p_1 \beta_1 + P_2 \beta_2}{E_z^2} - \frac{P_2 \beta_2}{E_z^2}$$

The expenditure share of the luxury good is an increasing function of disposable income E_z , if the preference parameter α is greater than the implied 'necessary expenditure share' ns_2 for given prices. Figure A4 illustrates this relationship.

$$ns_2 = \frac{P_2 \beta_2}{P_1 \beta_1 + P_2 \beta_2}$$

Aggregate demand for the basic good is the the sum of demand by all employed unskilled individuals (ue), unemployed unskilled individuals (uu), employed skilled individuals (se), and unemployed skilled individuals (su).

$$Q_I^D = Q_{ue,I}^D + Q_{uu,I}^D + Q_{se,I}^D + Q_{su,I}^D \quad (9)$$

Substituting in for disposable income into equation (9), group specific demand is given by

$$Q_{ke,I}^D = \left[\beta_1 + \frac{1-\alpha}{p_1} [(1-\tau_B)w_k - p_1 \beta_1 - P_2 \beta_2] \right] L_k \quad \text{for } k = u, s \quad (9a)$$

$$Q_{ku,I}^D = \left[\beta_1 + \frac{1-\alpha}{p_1} [r w_k - p_1 \beta_1 - P_2 \beta_2] \right] (V_k - L_k) \quad \text{for } k = u, s \quad (9b)$$

where L_k is employment and V_k is the population of skill-group k .

In a parallel fashion, aggregate demand for one variety of the differentiated good is the sum of demand of the four different groups in the economy.

$$q_{2,j}^D = q_{ue,2,j}^D + q_{uu,2,j}^D + q_{se,2,j}^D + q_{su,2,j}^D \quad (10)$$

where

$$q_{ke,j} = \left[\frac{p_{2,j}^{-\sigma}}{\sum_{i=1}^n p_{2,i}^{1-\sigma}} \left[(1 - \tau_B) w_k - p_l Q_{ke,l} \right] \right] L_k \quad \text{for } k = u, s \quad (10a)$$

$$q_{ku,j} = \left[\frac{p_{2,j}^{-\sigma}}{\sum_{i=1}^n p_{2,i}^{1-\sigma}} \left[r w_k - p_l Q_{ku,l} \right] \right] (V_k - L_k) \quad \text{for } k = u, s \quad (10b)$$

3.2 Firms Producing the Basic Good

Firms producing the basic good are assumed to be profit maximizing. Modelling a single firm that sets its price according to the marginal cost rule is identical to modelling $n \rightarrow \infty$ firms for the purpose of having perfect competition on the basic good market. Technology is described by a CES function.

$$Q_l = \kappa_{l,n} \left[v_{l,u} (\kappa_{l,u} L_{l,u})^{\theta_l} + v_{l,s} (\kappa_{l,s} L_{l,s})^{\theta_l} \right]^{\frac{1}{\theta_l}} \quad (11)$$

with $\theta_l < 1$, $0 < v_{l,k} < 1$ for $k = u, s$, $v_{l,u} + v_{l,s} = 1$,

and $\kappa_{l,k} > 0$ for $k = u, s, n$

$L_{l,u}$ and $L_{l,s}$ are the inputs of unskilled and skilled labor. $v_{l,j}$ are parameters of the production function that determine the skill intensity. $\kappa_{l,n}$ denotes neutral technical change, $\kappa_{l,u}$ denotes unskilled-specific technical change, and $\kappa_{l,s}$

denotes skilled-specific technical change. The associated minimum cost function is

$$C_I = \left[\delta_{I,u} (\lambda_{I,u} w_u)^{\phi_I} + \delta_{I,s} (\lambda_{I,s} w_s)^{\phi_I} \right]^{\frac{1}{\phi_I}} \lambda_{I,n} Q_I \quad (12)$$

where

$$\delta_{I,j} = v_{I,j}^{\frac{1}{1-\theta_I}} \text{ for } j = u, s, \quad \lambda_{I,j} = \frac{1}{\kappa_{I,j}} \text{ for } j = u, s, n \quad \text{and } \phi_I = \frac{\theta_I}{\theta_I - 1}$$

Unskilled and skilled labor demand is derived from the minimum cost function according to Shepard's Lemma.

$$L_{I,k} = \delta_{I,k} \lambda_{I,k}^{\phi_I} w_k^{\phi_I - 1} \left[\delta_{I,u} (\lambda_{I,u} w_u)^{\phi_I} + \delta_{I,s} (\lambda_{I,s} w_s)^{\phi_I} \right]^{\frac{1-\phi_I}{\phi_I}} \lambda_{I,n} Q_I \quad (13)$$

for $k = u, s$

Optimum supply is determined from profit maximization.

$$p_I = \left[\delta_{I,u} (\lambda_{I,u} w_u)^{\phi_I} + \delta_{I,s} (\lambda_{I,s} w_s)^{\phi_I} \right]^{\frac{1}{\phi_I}} \lambda_{I,n} \quad (14)$$

3.3 Firms Producing the Differentiated Luxury Goods

Firms producing the luxury good are also assumed to be profit maximizing subject to a CES technology. Production requires unskilled labor, skilled labor, and an aggregate intermediate service Q_3 .

$$q_{2j} =$$

$$\kappa_{2,n} \left[v_{2,u} (\kappa_{2,u} L_{2j,u})^{\theta_2} + v_{2,s} (\kappa_{2,s} L_{2j,s})^{\theta_2} + v_{2,d} (\kappa_{2,d} Q_{3,j})^{\theta_2} \right]^{\frac{1}{\theta_2}} \quad (15)$$

The m individual intermediate services $q_{3,j}$ are aggregated according to a CES function with parameter of differentiation μ .

$$Q_{3,j} = \left(\sum_{i=1}^m q_{3,j,i}^\mu \right)^{\frac{1}{\mu}} \quad (16)$$

Assuming a fixed cost component¹⁰

$$C_{2f,j} = w_u L_{2f,j,u} + w_s L_{2f,j,s}$$

the minimum cost function can be rewritten as

$$C_{2,j} = C_{2f,j} + \left[\delta_{2,u} (\lambda_{2,u} w_u)^{\phi_2} + \delta_{2,s} (\lambda_{2,s} w_s)^{\phi_2} + \delta_{2,d} (\lambda_{2,d} P_3)^{\phi_2} \right]^{\frac{1}{\phi_2}} \lambda_{2,n} q_{2,j} \quad (17)$$

$$\text{where } \delta_{2,j} = v_{2,j}^{\frac{1}{1-\theta_2}} \text{ for } j = u, s, d, \quad \lambda_{2,j} = \frac{1}{\kappa_{2,j}}$$

$$\text{for } j = u, s, d, n \quad \text{and } \phi_2 = \frac{\theta_2}{\theta_2 - 1}$$

The conditional factor demand functions in terms of the cost function result by Shepard's Lemma.

$$L_{2,j,k} = L_{2f,j,k} + \delta_{2,k} \lambda_{2,k}^{\phi_2} w_k^{\phi_2-1} \Theta^{\frac{1-\phi_2}{\phi_2}} \lambda_{2,n} q_{2,j} \quad \text{for } k = u, s \quad (18)$$

$$Q_{3,j} = \delta_{2,d} \lambda_{2,d}^{\phi_2} P_3^{\phi_2-1} \Theta^{\frac{1-\phi_2}{\phi_2}} \lambda_{2,n} q_{2,j} \quad (19)$$

¹⁰ This kind of fixed cost component was suggested by Krugman (1979).

$$\text{with } \Theta = \left[\delta_{2,u} (\lambda_{2,u} w_u)^{\phi^2} + \delta_{2,s} (\lambda_{2,s} w_s)^{\phi^2} + \delta_{2,d} (\lambda_{2,d} P_3)^{\phi^2} \right]$$

Demand for one variety of the intermediate service results directly from the aggregation function (16).

$$q_{3,j,i} = \frac{\frac{1}{p_{3,i}^{\mu-1}}}{\left[\sum_{h=1}^m \frac{\mu}{p_{3,h}^{\mu-1}} \right]^{\frac{1}{\mu}}} Q_{3,j} \quad (20)$$

The price index P_3 for the aggregate intermediate service is

$$P_3 = \left[\sum_{h=1}^m \frac{\mu}{p_{3,h}^{\mu-1}} \right]^{\frac{\mu-1}{\mu}} \quad (21)$$

Profit maximization yields supply of the j -th variety of the luxury good. The implicit supply function for the j -th variety of the luxury good can be written as a mark-up over marginal costs.

$$p_{2,j} = \frac{1}{\rho} \left[\delta_{2,u} (\lambda_{2,u} w_u)^{\phi^2} + \delta_{2,s} (\lambda_{2,s} w_s)^{\phi^2} + \delta_{2,d} (\lambda_{2,d} P_3)^{\phi^2} \right]^{\frac{1}{\phi^2}} \lambda_{2,n} \quad (22)$$

The number of firms producing the differentiated luxury good is determined from the zero-profit condition: Additional firms will enter the markets, as long as profits are positive. Firms will drop out of the markets, when profits are negative. Hence, in equilibrium,

$$\Pi_{2,j} = p_{2,j} q_{2,j} - C_{2,j} = 0 \quad (23)$$

holds.

3.4 Firms Producing the Intermediate Service

Firms producing the intermediate service are modelled in a parallel fashion to the firms producing the differentiated luxury good. Technology is described by a CES function in unskilled and skilled labor. There is no intermediate input. Production is associated with a fixed cost component. The minimum cost function is

$$C_{3,i} = C_{3f,i} + \left[\delta_{3,u} (\lambda_{3,u} w_u)^{\phi_3} + \delta_{3,s} (\lambda_{3,s} w_s)^{\phi_3} \right]^{\frac{1}{\phi_3}} \lambda_{3,n} q_{3,i} \quad (24)$$

The conditional factor demand functions for unskilled and skilled labor are

$$L_{3,i,k} = L_{3f,i,k} + \delta_{3,k} \lambda_{3,k}^{\phi_3} \phi_3 w_k^{\phi_3-1} \left[\delta_{3,u} (\lambda_{3,u} w_u)^{\phi_3} + \delta_{3,s} (\lambda_{3,s} w_s)^{\phi_3} \right]^{\frac{1}{\phi_3}} \lambda_{3,n} q_{3,i} \quad (25)$$

for $k = u, s$

Profit maximization yields supply of the j -th variety of the intermediate service.

$$p_{3,i} = \frac{1}{\mu} \left[\delta_{3,u} (\lambda_{3,u} w_u)^{\phi_3} + \delta_{3,s} (\lambda_{3,s} w_s)^{\phi_3} \right]^{\frac{1}{\phi_3}} \lambda_{3,n} \quad (26)$$

The number of firms producing the intermediate service is determined from the zero-profit condition.

$$\Pi_{3,i} = p_{3,i} q_{3,i} - C_{3,i} = 0 \quad (27)$$

3.5 Labor Supply

Labor supply is modelled in two different ways: (i) Under the assumption of a flexible labor markets; and (ii) Under the assumption of rigid labor markets, characterized by a monopoly union. The flexible labor market can be thought of as representing the United States. The rigid labor market can be thought of as representing Germany.

For the flexible labor market case, labor supply is independent of the wage rate: Fully flexible wages lead to full employment. Labor supply L_k is then given by the population V_k :

$$L_k = V_k \quad \text{for } k = u, s \quad (28)$$

For the rigid labor market case, I assume that labor supply is determined by a monopoly union for each skill group. There are several other approaches to modelling a rigid labor market. In particular, bargaining models would appear as a natural starting point. However, such bargaining models are unattractive for a variety of reasons.¹¹ Although the monopoly union approach (e.g. Oswald 1982, Gottfries and Horn 1987) appears as a poor approximation, it may actually be quite suited to describe the German wage bargaining process.¹² Unions produce

¹¹ The right-to-manage approach (e.g. Nickell and Andrews 1983, Layard et al. 1991) implies that part of the rent that is bargained for is neither captured by the union, nor by firms. The efficient-bargain approach (e.g. McDonald and Solow 1981, Nickell and Andrews 1983) assumes bargaining over both wages and employment which is not typical for the German labor market. Both bargaining models assume the existence of profits. However, in macroeconomic models it is required that the adding-up condition holds. There are no profits in excess of factor income that could be bargained about. Most authors deal with this problem by letting the agents bargain about the return to capital (e.g. Hoel 1990, or Lockwood 1990). This approach would require adding capital as a fourth factor of production to the model. Since capital would serve no other purpose in the model, the increased complexity is too high a cost.

¹² For an overview of the German wage bargaining process see Siebert (1998 and 1997) or Franz (1996).

the first wage offer. The employers' association reacts to this offer by implicitly announcing the change in employment that would follow from the proposed wage increase. The union in turn revises its wage proposal until a wage has been agreed upon.

There is a monopoly union for each skill group that sets the wage for its skill group across all branches. Each union maximizes a Stone-Geary type utility function with respect to the wage, subject to aggregate labor demand (cf. Franz 1996: 286).

$$G_k = (w_k - \bar{w}_k)^{\gamma_k} (L_k - \bar{L}_k)^{1-\gamma_k} \quad (29)$$

with $0 < \gamma_k < 1$

$$\text{s.t.} \quad L_k = L_{l,k} + \sum_{j=1}^n L_{2,j,k} + \sum_{i=1}^m L_{3,i,k} \quad (30)$$

for $k = u, s$

Utility is an increasing function in the wage rate and employment. A positive utility is generated only, when both the wage and employment exceed a certain minimum level. For the minimum wage level, one can think of as a subsistence level, or as the market clearing wage in a flexible labor market. The exponent γ_k defines the weight, the union places on its wage objective relative to its employment objective.

The wage equation results from utility maximizing. The wage is the required minimum wage plus employment exceeding minimum employment weighed with derivative of employment with respect to the wage and the weights from the utility function.

$$w_k = \bar{w}_k + \frac{\gamma_k}{\gamma_k - 1} (L_k - \bar{L}_k) \left(\frac{\partial L_k}{\partial w_k} \right)^{-1} \quad (31)$$

The tax on wages to finance unemployment benefits is endogenous to the model. Tax revenue must equal expenditure on unemployment benefits.

$$\tau_B [w_u L_u + w_s L_s] = r [w_u (V_u - L_u) + w_s (V_s - L_s)] \quad (32)$$

Solving for the tax rate yields

$$\tau_B = r \left[\frac{w_u V_u + w_s V_s}{w_u L_u + w_s L_s} - 1 \right] \quad (33)$$

4 Simulation Results

The model is simulated under different assumptions to analyze how different technology shocks and different transmission mechanisms impact on employment and wages. First, a reference scenario is simulated for both the flexible and the rigid labor market case. Second, the impact of unskilled-specific, skilled-specific, and neutral technical change is simulated for both labor market cases by a 10 percent shock in the respective technology parameter across all firms. This is done for individuals with Stone-Geary preferences and for individuals with Cobb-Douglas preferences to highlight the importance of the shift in consumer expenditure. The presentation of results in the text is restricted to a set of core variables that serve to illustrate the main points.¹³

The exogenous parameters of the model (Appendix 3.1) are set to roughly match the West-German economy in the nineties. The population is set equal to

¹³ The complete results of the simulations are presented in Appendix 3.2.

the total labor force at 30 million people.¹⁴ 45 percent of the employed are skilled. This translates into around 14 million skilled and 16 million unskilled individuals in the population.¹⁵ The preference parameter α is set to 0.9. In the Cobb-Douglas case, the expenditure share for the aggregate luxury good is set equal to the expenditure share in the Stone-Geary reference case. The minimum quantity of the basic good is 0.25. There is no minimum quantity requirement for the aggregate luxury good. For the rigid labor market case, the replacement ratio is set to 0.6.

Estimates of the elasticity of substitution between skilled and unskilled labor vary between different studies and levels of aggregation. See Steiner and Mohr 1998 and Hamermesh 1993 for a survey of empirical studies. The estimates range between 3 at an aggregate level and very small values close to zero at disaggregated levels. For the simulation, the elasticity of substitution is set to 0.5 for all sectors. The factor weights in the production functions are set to make the basic good sector unskilled intensive, and the luxury goods sector as well as the intermediate service sector skilled intensive; the intermediate service sector is more skilled intensive than the luxury goods sector. In both sectors, the fixed cost component uses one unit of unskilled labor and two units of skilled labor.

For the reference case, the parameters capturing unskilled-specific technical change, skilled-specific technical change, neutral technical change, and the parameters capturing service-specific technical change are set to unity. The relative wage of the skilled to the unskilled that results in the reference scenario

¹⁴ All aggregate data are taken from Sachverständigenrat (1997).

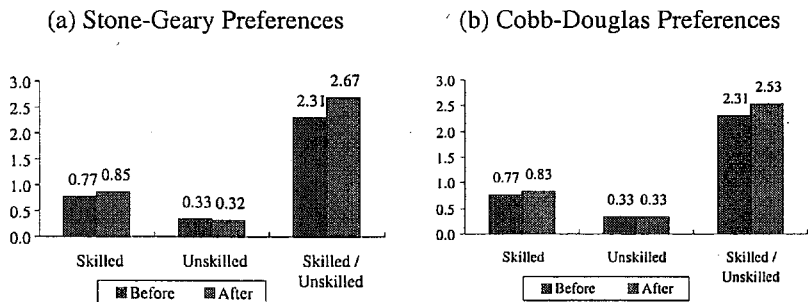
¹⁵ Cf. Schimmelpfennig (1998). The respective unemployment rates were assumed to be 4 percent for the skilled and 15 percent for the unskilled (Christensen and Schimmelpfennig 1998: 181).

is 2.3. For the United States, the ratio of the 9th decile to the 1st decile of the earnings distribution is 4.1 in 1993 and 4.4 in 1995. For Germany, the same ratio is 2.5 in 1990 and 2.3 in 1993 (OECD 1996: pp. 61, Table 3.1). Between 1984 and 1995, the ratio of average wages of male high skilled workers to low skilled workers in Germany is 2.2; and the ratio of average wages of male high skilled workers to medium skilled workers is 1.26 (Christensen and Schimmelpfennig 1998: 182).

4.1 Flexible Labor Markets

For flexible labor markets, unskilled-specific technical change leads to an increase in the relative wage of the skilled (Figure 1). When individuals have SG preferences, expenditure shifts towards the luxury good as technical change increases income. In this case, the unskilled wage falls and the skilled wage rises. However, when individuals have CD preferences and expenditure shares remain constant, the wage of the unskilled does not change.

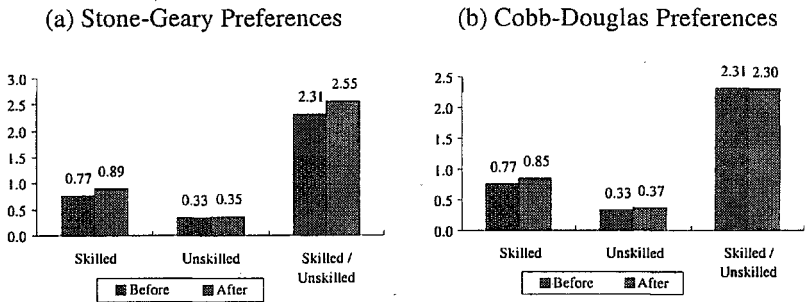
Figure 1 – Flexible Labor Markets: Impact of Unskilled-Specific Technical Change on Wages



For neutral technical change and SG preferences, unskilled and skilled wages both rise (Figure 2). Since skilled wages rise by more than unskilled wages, the

relative wage of the skilled rises; the rise is less pronounced than with unskilled-specific technical change, because neutral technical change affects both skill-groups directly. For CD preferences, the results reverse. Unskilled wages rise by more than skilled wages; the relative wage of the skilled falls slightly.

Figure 2 – Flexible Labor Markets: Impact of Neutral Technical Change on Wages



For skilled-specific technical change, the results are just the reverse of unskilled specific technical change: The unskilled wage rises by more than the skilled wage. Therefore, the relative wage of the skilled falls. Service-specific technical change leads to no significant impact on the economy.

Comparing the simulation results to the U.S. experience, unskilled-specific and neutral technical change lead to the observed rise in the relative wage of the skilled.¹⁶ Assuming that the fall in the real wage of unskilled workers in the United States was a temporary phenomenon during adjustment, unskilled-specific and neutral technical change are consistent with the empirical

¹⁶ In the case of neutral technical change, this holds only for individuals with SG preferences.

evidence.¹⁷ However, a fall in the wage of the unskilled results only for unskilled technical change when there is a shift in consumption towards the more skill-intensive luxury good. The shift in consumption must therefore be regarded as an important force driving relative labor demand.

4.2 Unions with Stone-Geary Preferences

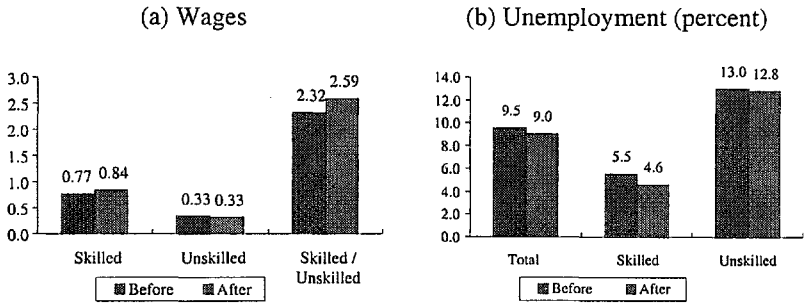
If unions are assumed to have SG-preferences in wages and employment, unskilled specific technical change leads to a rising relative wage of the skilled; the skilled wage and the unskilled wage both rise (Figure 3)¹⁸. The unemployment rates for both skill groups fall. The unions of both skill-groups balance their wage and employment objectives: Any productivity gain is translated into a wage gain and an employment gain. However, because the shift in expenditure magnifies the direct effect of unskilled-specific technical change, the relative wage of the skilled can rise. The wage share of the skilled rises in all branches of the economy.

For neutral technical change, the relative wage of the skilled rises (Figure 4). Now, not only the skilled wage, but also the unskilled wage rises. Compared to unskilled-specific technical change, only the expenditure shift affects the unskilled adversely, so that their wage can rise, too. Unemployment rates fall for both skill groups. The fall is more pronounced than for unskilled-specific technical change, because the average labor productivity gain is greater. Again, the wage share of the skilled rises across all branches of the economy.

¹⁷ There is some empirical evidence that the fall in the real wage of the unskilled has been reversed (cf. Council of Economic Advisors 1995).

¹⁸ For the rigid labor market case, I look only at the results for individuals with SG preferences. Results for individuals with CD preferences are reported in the appendix. The difference between the model with a shift in consumption and the model without a shift in consumption are similar to the differences in the flexible labor market case.

Figure 3 – Unions: Impact of Unskilled Specific Technical Change
(Individuals with Stone-Geary Preferences)

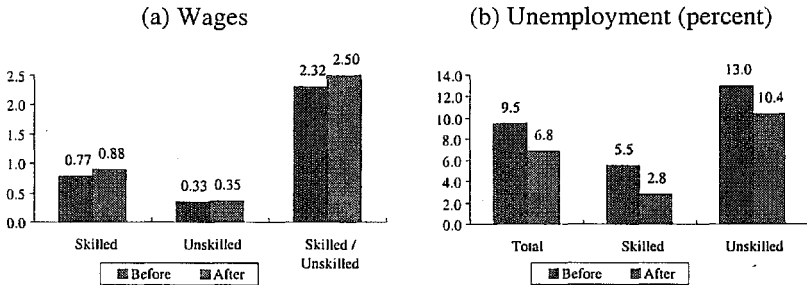


Opposite to the findings for a flexible labor market, skilled-specific technical change leads to a rise in the relative wage of the skilled; here the adverse direct effect of technical change is countered by the indirect effect through the expenditure shift. The unemployment rates fall for both skill groups. However, the wage share for the skilled falls across all branches of the economy. Service-specific technical change has no significant impact.

Comparing the simulation results to the German experience, neither type of technical change reproduces the stylized facts. Germany exhibits fairly constant relative wages, fairly constant unemployment rates for the skilled, a pronounced increase in unemployment among the unskilled, and an increase in total unemployment (cf. Christensen and Schimmelpfennig 1998). Still, the theoretical results are intuitively plausible. The unions' preferences were assumed to increase in wages and employment. Therefore, any productivity gain is divided between wage increases and unemployment reductions.¹⁹

¹⁹ The results do not change when the tax to finance the unemployment benefits payments is divided between employees and employers as it is the case in Germany.

Figure 4 – Unions: Impact of Neutral Technical Change
(Individuals with Stone-Geary Preferences)



4.3 Constant Wage Differential Across Skill Groups

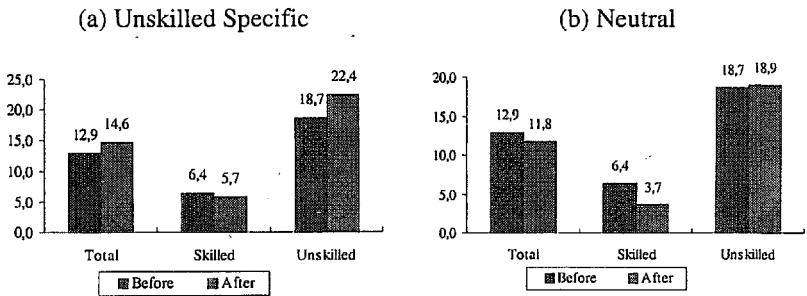
The constant wage differential across skill groups is a defining element of the recent German labor market experience. In the seventies, unions pursued a "solidaristic" wage policy that succeeded in narrowing the wage gap between skilled and unskilled workers. In the eighties and nineties, the policy stance has been relaxed and the relative wage of the skilled has remained constant (e.g. Steiner and Wagner 1998 and Christensen and Schimmelpfennig 1998). This empirical finding is imposed upon the model: The wage for skilled labor is set by a monopoly union as above. The wage for unskilled labor is set at one half of the wage for skilled labor.²⁰

Unskilled-specific as well as neutral technical change lead to an increase in the aggregate unemployment rate (Figure 5). This aggregate effect is the net effect of opposing developments for the two skill groups. The unemployment rate for the skilled falls, because the union that sets the wage for the skilled still

²⁰ Alternatively, I have assumed full employment for skilled labor resulting from a flexible labor market for the skilled. The results do not change fundamentally.

balances its wage and employment objective. Technical change is turned into wage and employment gains. However, the unemployment rate for the unskilled increases. By fixing the unskilled wage to the skilled wage, wage increases for the unskilled exceed the gain in labor productivity. Hence, employment of the unskilled is reduced until the wage again matches the marginal product.

Figure 5 – Constant Wage Differential: Impact of Technical Change on the Unemployment Rate in percent (Individuals with Stone-Geary Preferences)



5 Summary and Outlook

The secular shift in relative labor demand from unskilled to skilled workers across OECD countries is to a large extent still an unresolved phenomenon. Most theoretical explanations have so far been empirically rejected. The observed shift is thus attributed to a skill-biased technical change – a concept that some authors call a "label for our ignorance" (Gottschalk and Smeeding 1997: 649).

The impact of different types of technical change on relative labor demand has been analyzed in a closed-economy general equilibrium model. A flexible labor

market case and two rigid labor market cases were considered. With rising income, expenditure shifted towards more skill-intensive goods.

Unskilled-specific technical change and neutral technical change have both lead to a rise in the relative wage of the skilled in the flexible and the rigid labor market case. Unemployment arose only in the rigid labor market case: However given monopoly unions that consider wage and employment, technical change lead to a fall in the unemployment rates of both skill groups. Only under the assumption of a constant relative wage was there an increase in unemployment among the unskilled.

The model presented provides some preliminary answers to the question "Whodunnit?" Skill-biased technical change is either unskilled-specific technical change, increasing the productivity of unskilled labor, or neutral technical change, increasing the productivity of both types of labor. Moreover, skill-biased technical change is an expenditure shift towards skill-intensive goods. However, the model suggests that skill-biased technical change is not a skilled-specific technical change which increases the productivity of skilled labor.

By itself, technical change is not responsible for rising unemployment. Even the presence of unions does not lead to a *rise* in unemployment. Therefore, the model presented here will be extended to capture an additional rigidity that is present in the German labor market: imperfect mobility of workers between occupations and branches. In particular, mobility between jobs in physical production and the production of services appears to be very low. (e.g. Klodt et al. 1997, Paqué 1996 and 1995). Workers released in declining industries have difficulties finding new jobs in expanding industries. They are effectively locked in due to a lack of qualification. If wages are determined in the expanding parts of the economy, unemployment among (unskilled) workers from declining industries rises.

Appendix 1 – Figures

Figure A1 – Outline of Individual Behavior

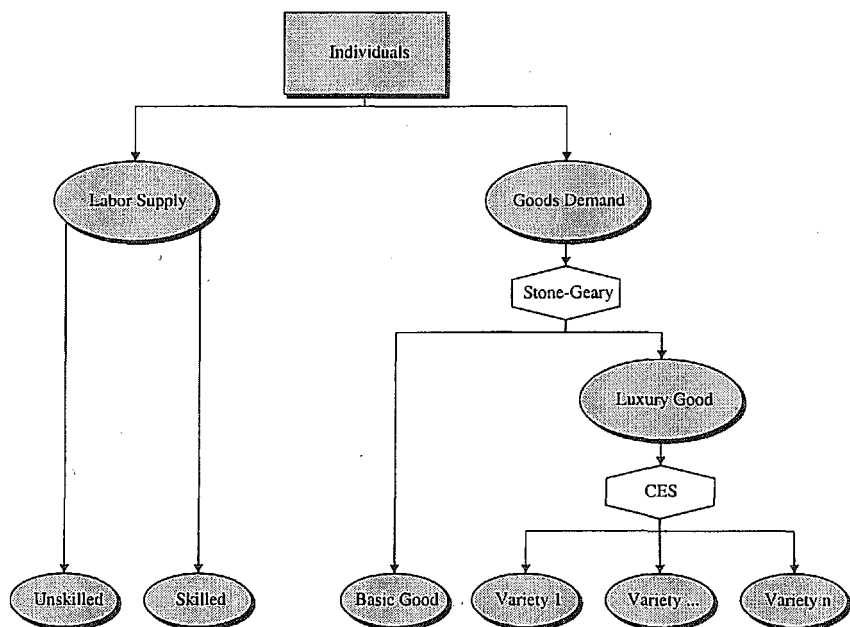


Figure A2 – Outline of the Production Tree

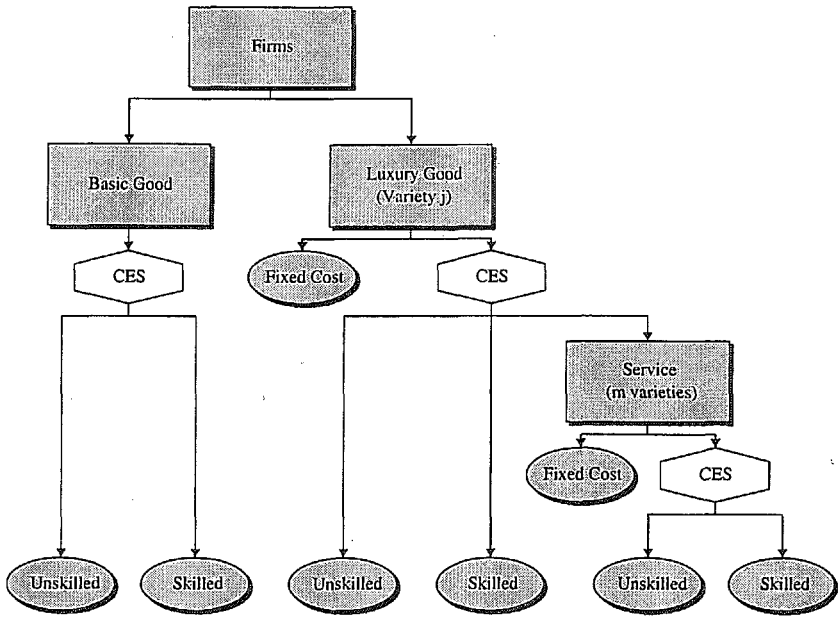


Figure A3 – Indifference Curve of a Stone-Geary (SG) and a Cobb-Douglas (CD) Preference Function

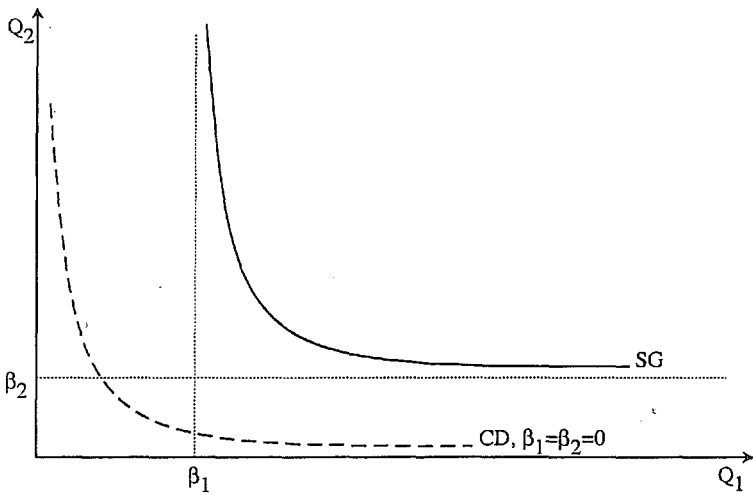
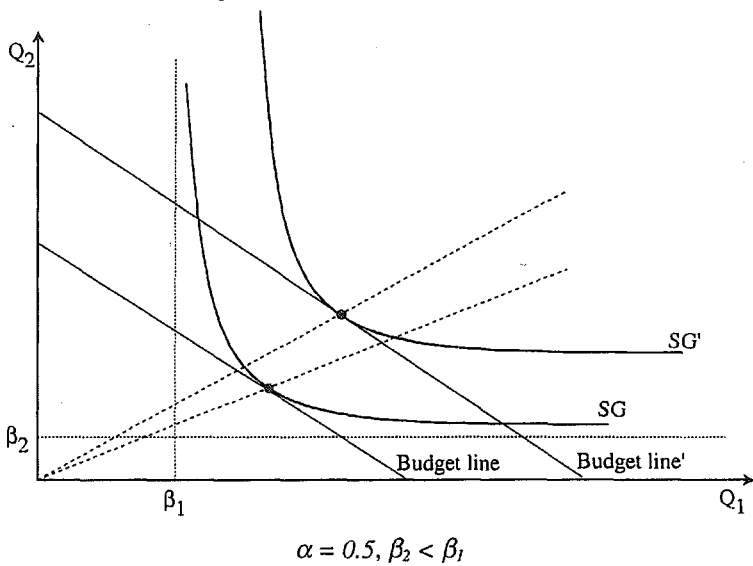


Figure A4 – Disposable Income and Expenditure Shares for SG Preferences



Appendix 2 – Derivations of the Model

Appendix 2.1 – Individuals

An individual's utility function is given by

$$U_z = (1 - \alpha) \log(Q_{z,1} - \beta_1) + \alpha \log(Q_{z,2} - \beta_2) \quad (1)$$

where $0 < \alpha < 1$, $Q_{z,j} - \beta_j > 0$ for $j = 1, 2$

The differentiated good $Q_{z,2}$ is a composite of all available varieties. The different varieties are aggregated by means of a CES-function (2).

$$Q_{z,2} = \left[\sum_{i=1}^n q_{z,2,i}^\rho \right]^{\frac{1}{\rho}} \quad (2)$$

The budget constraint is given by

$$E_z = p_1 Q_{z,1} + \sum_{i=1}^n p_{2,i} q_{z,2,i} \quad (3)$$

where p is the price of the respective good.

Individuals maximize their preference function subject to the budget constraint.

The Lagrangian Λ is given by

$$\begin{aligned} \Lambda = & (1 - \alpha) \log(Q_{z,1} - \beta_1) + \alpha \log \left(\left(\sum_{i=1}^n q_{z,2,i}^\rho \right)^{\frac{1}{\rho}} - \beta_2 \right) \\ & + \xi \left[E_z - p_1 Q_{z,1} - \sum_{i=1}^n p_{2,i} q_{z,2,i} \right] \end{aligned} \quad (A1)$$

The first-order conditions are

$$\frac{\partial \Lambda}{\partial Q_{z,1}} = \frac{(1-\alpha)}{Q_{z,1} - \beta_1} - \xi p_1 = 0 \quad (\text{A2a})$$

$$\frac{\partial \Lambda}{\partial Q_{z,2}} = \frac{\alpha}{\left(\sum_{i=1}^n q_{z,2,i}^\rho\right)^{\frac{1}{\rho}} - \beta_2} - \frac{1}{\rho} \left(\sum_{i=1}^n q_{z,2,i}^\rho\right)^{\frac{1-\rho}{\rho}} \sum_{i=1}^n \frac{\partial q_{z,2,i}^\rho}{\partial Q_{z,2}} - \xi \sum_{i=1}^n p_{2,i} \frac{\partial q_{z,2,i}}{\partial Q_{z,2}} = 0 \quad (\text{A2b})$$

$$\frac{\partial \Lambda}{\partial q_{z,j}} = \frac{\alpha}{\left(\sum_{i=1}^n q_{z,2,i}^\rho\right)^{\frac{1}{\rho}} - \beta_2} \left(\sum_{i=1}^n q_{z,2,i}^\rho\right)^{\frac{1-\rho}{\rho}} q_{z,2,j}^{\rho-1} - \xi p_{2,j} = 0 \quad (\text{A2c})$$

$$\frac{\partial \Lambda}{\partial \xi} = E_z - p_1 Q_{z,1} - \sum_{i=1}^n p_{2,i} q_{z,2,i} = 0 \quad (\text{A2d})$$

First, equation (A2c) and (A2d) are used to determine the optimal demand for the j -th variety of the differentiated good. Dividing equation (A2c) for $q_{z,2,i}$ by equation (A2c) for $q_{z,2,j}$ and solving for $q_{z,2,i}$ yields

$$q_{z,2,i} = \left(\frac{p_{2,i}}{p_{2,j}}\right)^{\frac{1}{\rho-1}} q_{z,2,j} \quad (\text{A3})$$

Substituting into the budget constraint (A2d) and solving for $q_{z,2,j}$ yields the demand for one variety of the luxury good.

$$q_{z,2,j} = \frac{\frac{1}{\rho-1} p_{2,j}}{\sum_{i=1}^n \frac{\rho}{\rho-1} p_{2,i}} (E_z - p_l Q_{z,1}) \quad (\text{A4})$$

Using the elasticity of substitution σ between any two varieties,

$$\sigma = \frac{\partial \frac{q_{z,2,i}}{q_{z,2,j}}}{\partial \frac{p_{2,j}}{p_{2,i}}} \frac{p_{2,i} q_{z,2,j}}{p_{2,j} q_{z,2,i}} = \frac{1}{1-\rho}$$

the demand function can be rewritten as

$$q_{z,2,j} = \frac{p_{2,j}^{-\sigma}}{\sum_{i=1}^n p_{2,i}^{1-\sigma}} (E_z - p_l Q_{z,1}) \quad (\text{A5})$$

The price index of the aggregate luxury good can be derived by substituting the demand function (A4) into the aggregation function of the luxury good (2).

$$Q_{z,2} = \left(\sum_{i=1}^n \frac{\rho}{\rho-1} p_{2,i} \right)^{\frac{1-\rho}{\rho}} (E_z - p_l Q_{z,1}) \quad (\text{A6})$$

Using the elasticity of substitution, the budget constraint and rearranging terms yields.

$$P_2 Q_{z,2} = \left(\sum_{i=1}^n p_{2,i}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} Q_{z,2} \quad (\text{A7})$$

Hence, the price index for the aggregate luxury good is given by

$$P_2 = \left(\sum_{i=1}^n p_{2,i}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \quad (5)$$

In the optimum, demand for any two varieties of the luxury good is identical. From the supply side, prices are determined by marginal costs, which are a function of wages (see below). Labor mobility ensures identical wages across firms. Therefore, prices are also identical. Since relative demand of any two varieties is a function of their relative prices only (A5), it follows that demand is identical across varieties.

Now, optimal demand for the basic good and the aggregate luxury good can be determined from equations (A2a), (A2b), and (A2d). First, the partial derivatives

$$\frac{\partial Q_{z,2}}{\partial q_{z,2,j}^\rho} = \frac{1}{\rho} \left(\sum_{i=1}^n q_{z,2,i}^\rho \right)^{\frac{1-\rho}{\rho}}$$

$$\frac{\partial Q_{z,2}}{\partial q_{z,2,j}} = \left(\sum_{i=1}^n q_{z,2,i}^\rho \right)^{\frac{1-\rho}{\rho}} q_{z,2,j}^{\rho-1}$$

are substituted into (A2b).

$$\frac{\alpha}{\left(\sum_{i=1}^n q_{z,2,i}^\rho \right)^{\frac{1}{\rho}} - \beta_2} \frac{1}{\rho} \left(\sum_{i=1}^n q_{z,2,i}^\rho \right)^{\frac{1-\rho}{\rho}} \sum_{i=1}^n \rho \left(\sum_{i=1}^n q_{z,2,i}^\rho \right)^{\frac{\rho-1}{\rho}} =$$

$$\xi \sum_{i=1}^n p_{2,i} \left(\sum_{i=1}^n q_{z,2,i}^\rho \right)^{\frac{\rho-1}{\rho}} q_{z,2,j}^{1-\rho}$$

Collecting terms and simplifying on the left-hand side and using the property that demand for each variety is identical in the optimum on the right-hand side yields

$$\frac{\alpha}{\left(\sum_{i=1}^n q_{z,2,i}^\rho\right)^{\frac{1}{\rho}} - \beta_2} n = \xi \left(\sum_{i=1}^n q_{z,2,i}^\rho\right)^{\frac{\rho-1}{\rho}} q_{z,2,j}^{-\rho} \sum_{i=1}^n p_{2,i} q_{z,2,i}$$

Using the definition of $Q_{z,2}$ and P_2 and simplifying leads to the revised first-order condition for the aggregate luxury good.

$$\frac{\alpha}{Q_{z,2} - \beta_2} = \xi P_2 \quad (\text{A2b'})$$

Dividing (A2b') through (A2a) and solving for $Q_{z,2}$ yields

$$Q_{z,2} = \frac{\alpha}{1-\alpha} \frac{p_1}{p_2} (Q_{z,1} - \beta_1) + \beta_2 \quad (\text{A8})$$

Substituting into the budget constraint (A2d)

$$E_z - p_1 Q_{z,1} - P_2 \left(\frac{\alpha}{1-\alpha} \frac{p_1}{P_2} (Q_{z,1} - \beta_1) + \beta_2 \right) = 0$$

The demand function for the basic good results from solving for $Q_{z,1}$.

$$Q_{z,1} = \beta_1 + \frac{1-\alpha}{p_1} [E_z - p_1 \beta_1 - P_2 \beta_2] \quad (\text{A9})$$

Likewise, the demand function for the aggregate luxury good results as

$$Q_{z,2} = \beta_2 + \frac{\alpha}{P_2} [E_z - p_1 \beta_1 - P_2 \beta_2] \quad (\text{A10})$$

Appendix 2.2 – Firms

To minimize appendix space, only the optimization calculus of a firm producing one variety of the luxury good is shown. The two other types of firms follow in a parallel fashion.

Firms producing the luxury good are also assumed to be profit maximizing subject to a CES technology. Production requires unskilled labor, skilled labor, and an aggregate intermediate service Q_3 .

$$q_{2j} = \kappa_{2,n} \left[\frac{v_{2,u} (\kappa_{2,u} L_{2j,u})^{\theta_2} + v_{2,s} (\kappa_{2,s} L_{2j,s})^{\theta_2} + v_{2,d} (\kappa_{2,d} Q_{3,j})^{\theta_2}}{\theta_2} \right]^{\frac{1}{\theta_2}} \quad (15)$$

The individual intermediate services $q_{3,j}$ are aggregated according to a CES function.

$$Q_{3,j} = \left(\sum_{i=1}^m q_{3,j,i}^{\mu} \right)^{\frac{1}{\mu}} \quad (16)$$

The cost function is given by

$$C_{2,j} = C_{2f,j} + w_u L_{2,j,u} + w_s L_{2,j,s} + \sum_{i=1}^m p_3 q_{3,j,i} \quad (A11)$$

where $C_{2f,j}$ is a fixed cost component. Each firm needs to employ a fixed number of unskilled workers $L_{2f,j,u}$ and a fixed number of skilled workers $L_{2f,j,s}$ that produce, for example, an administrative output which is not part of the output $q_{2,j}$.

$$C_{2f,j} = w_u L_{2f,j,u} + w_s L_{2f,j,s} \quad (A12)$$

The optimizing behavior is described by minimization of the cost function (A11) subject to the production technology (15). The Lagrangian is

$$\Lambda = C_{2f,j} + w_u L_{2,j,u} + w_s L_{2,j,s} + \sum_{i=1}^m p_{3,i} q_{3,j,i} + \xi \left[b^{\theta_2} - a_u L_{2,j,u}^{\theta_2} - a_s L_{2,j,s}^{\theta_2} - a_d \left(\sum_{i=1}^m q_{3,j,i}^\mu \right)^{\frac{\theta_2}{\mu}} \right] \quad (\text{A13})$$

$$\text{with } b = \left(\frac{q_{2,j}}{\kappa_{2,n}} \right), \quad a_u = v_{2,u} \kappa_{2,u}^{\theta_2}, \quad a_s = v_{2,s} \kappa_{2,s}^{\theta_2} \text{ and } a_d = v_{2,d} \kappa_{2,d}^{\theta_2}$$

The first-order conditions are

$$\frac{\partial \Lambda}{\partial L_{2,j,u}} = w_u - \xi a_u \theta_2 L_{2,j,u}^{\theta_2-1} = 0 \quad (\text{A14a})$$

$$\frac{\partial \Lambda}{\partial L_{2,j,s}} = w_s - \xi a_s \theta_2 L_{2,j,s}^{\theta_2-1} = 0 \quad (\text{A14b})$$

$$\frac{\partial \Lambda}{\partial Q_{3,j}} = \sum_{i=1}^m p_{3,i} \frac{\partial q_{3,j,i}}{\partial Q_{3,j}} - \xi a_d \frac{\theta_2}{\mu} \left(\sum_{i=1}^m q_{3,j,i}^\mu \right)^{\frac{\theta_2-\mu}{\mu}} \sum_{i=1}^m \frac{\partial q_{3,j,i}^\mu}{\partial Q_{3,j}} = 0 \quad (\text{A14c})$$

$$\frac{\partial \Lambda}{\partial q_{3,j,i}} = p_{3,i} - \xi a_d \theta_2 \left(\sum_{k=1}^m q_{3,j,k}^\mu \right)^{\frac{\theta_2-\mu}{\mu}} q_{3,j,i}^{\mu-1} = 0 \quad (\text{A14d})$$

$$\frac{\partial \Lambda}{\partial \xi} = b^{\theta_2} - a_u L_{2,j,u}^{\theta_2} - a_s L_{2,j,s}^{\theta_2} - a_d \left(\sum_{i=1}^m q_{3,j,i}^\mu \right)^{\frac{\theta_2}{\mu}} = 0 \quad (\text{A14e})$$

First, demand for a single variety of the intermediate service is derived. Dividing equation (A14d) for variety i by equation (A14d) for variety h of the intermediate service and solving for variety i yields

$$q_{3,j,i} = \left(\frac{p_{3,h}}{p_{3,i}} \right)^{\frac{1}{\mu-1}} q_{3,j,i} \quad (\text{A15})$$

Substituting into the production function (A14d), using the definition of the aggregate intermediate service²¹ and solving for $q_{3,j,i}$ yields the demand for one variety of the intermediate service.

$$q_{3,j,i} = \frac{p_{3,i}^{\frac{1}{\mu-1}}}{\left[\sum_{h=1}^m p_{3,h}^{\frac{\mu}{\mu-1}} \right]^{\frac{1}{\mu}}} Q_{3,j} \quad (20)$$

The price index P_3 for the aggregate intermediate service is derived by multiplying through with $p_{3,i}$ and taking the sum over all i varieties on both sides.

$$\sum_{i=1}^m p_{3,i} q_{3,j,i} = \sum_{i=1}^m p_{3,i} \frac{p_{3,i}^{\frac{1}{\mu-1}}}{\left[\sum_{h=1}^m p_{3,h}^{\frac{\mu}{\mu-1}} \right]^{\frac{1}{\mu}}} Q_{3,j} \quad (\text{A16})$$

The left hand side equals the price index P_3 times the aggregate intermediate service $Q_{3,j}$. Dividing through by $Q_{3,j}$ and simplifying the right hand side yields

²¹ This is equivalent to substituting into the aggregation function of the intermediate service.

the price index for the aggregate intermediate service as a function of the prices of the varieties of the intermediate service.

$$P_3 = \left[\sum_{h=1}^m p_{3,h}^{\frac{\mu}{\mu-1}} \right]^{\frac{\mu-1}{\mu}} \quad (21)$$

Next, the demand functions for unskilled labor, skilled labor, and the aggregate intermediate service are determined. In a first step, the first-order condition (A14c) for the aggregate intermediate service is rewritten using the derivatives

$$\frac{\partial Q_{3,j}}{\partial q_{3,j,i}} = \left(\sum_{i=1}^m q_{3,j,i}^{\mu} \right)^{\frac{1-\mu}{\mu}} q_{3,j,i}^{\mu-1} \quad \text{and}$$

$$\frac{\partial Q_{3,j}}{\partial q_{3,j,i}^{\mu}} = \frac{1}{\mu} \left(\sum_{i=1}^m q_{3,j,i}^{\mu} \right)^{\frac{1-\mu}{\mu}}.$$

The first-order condition (A14c) becomes

$$\sum_{i=1}^m p_{3,i} \left(\sum_{i=1}^m q_{3,j,i}^{\mu} \right)^{\frac{\mu-1}{\mu}} q_{3,j,i}^{1-\mu} = \xi a_d \frac{\theta_2}{\mu} \left(\sum_{i=1}^m q_{3,j,i}^{\mu} \right)^{\frac{\theta_2-\mu}{\mu}} \left(\sum_{i=1}^m \mu \left(\sum_{i=1}^m q_{3,j,i}^{\mu} \right)^{\frac{\mu-1}{\mu}} \right)$$

Simplifying and collecting terms²²

$$q_{3,j,k}^{-\mu} \sum_{i=1}^m p_{3,i} q_{3,j,i} = \xi a_d \theta_2 \left(\sum_{i=1}^m q_{3,j,i}^{\mu} \right)^{\frac{\theta_2-\mu}{\mu}} m$$

²² Again using the property that all varieties of the intermediate service are equal in the optimum for the same reasons discussed above.

The sum on the left hand side is just aggregate costs of the intermediate services. Using the aggregate price index of the intermediate services and the definition of the aggregate intermediate services yields

$$P_3 Q_{3,j} = \xi a_d \theta_2 m Q_{3,j}^{\theta_2} \left(\sum_{i=1}^m q_{3,j,i}^\mu \right)^{-1} q_{3,j,k}^\mu$$

The last two terms on the right hand side are just $1/m$. Dividing through by $Q_{3,j}$ yields the simplified first-order condition that would also have arisen, if the aggregate intermediate service had been substituted into the Lagrangian.

$$P_3 = \xi a_d \theta_2 Q_{3,j}^{\theta_2-1} \quad (\text{A14cc})$$

Rewriting conditions (A14a), (A14b), and (A14cc)

$$L_{2,j,u} = \left(\frac{w_u}{\xi a_u \theta_2} \right)^{\frac{1}{\theta_2-1}} \quad (\text{A14a'})$$

$$L_{2,j,s} = \left(\frac{w_s}{\xi a_s \theta_2} \right)^{\frac{1}{\theta_2-1}} \quad (\text{A14b'})$$

$$Q_{3,j} = \left(\frac{P_3}{\xi a_d \theta_2} \right)^{\frac{1}{\theta_2-1}} \quad (\text{A14c'})$$

Substituting (A14a') through (A14c') into the production function (A14e)

$$b^{\theta_2} = a_u \left(\frac{w_u}{\xi a_u \theta_2} \right)^{\frac{\theta_2}{\theta_2-1}} + a_s \left(\frac{w_s}{\xi a_s \theta_2} \right)^{\frac{\theta_2}{\theta_2-1}} + a_d \left(\frac{P_3}{\xi a_d \theta_2} \right)^{\frac{\theta_2}{\theta_2-1}}$$

and solving for $(\xi \theta_2)^{\frac{-1}{\theta_2-1}}$

$$\left(\frac{1}{\xi\theta_2}\right)^{\frac{1}{\theta_2-1}} = \left[a_u \left(\frac{w_u}{a_u}\right)^{\frac{\theta_2}{\theta_2-1}} + a_s \left(\frac{w_s}{a_s}\right)^{\frac{\theta_2}{\theta_2-1}} + a_d \left(\frac{P_3}{a_d}\right)^{\frac{\theta_2}{\theta_2-1}} \right]^{-\frac{1}{\theta_2}} b$$

Substituting back into (A14a') through (A14c') gives the conditional factor demand functions.

$$L_{2,j,u} =$$

$$\left(\frac{w_u}{a_u}\right)^{\frac{1}{\theta_2-1}} \left[a_u \left(\frac{w_u}{a_u}\right)^{\frac{\theta_2}{\theta_2-1}} + a_s \left(\frac{w_s}{a_s}\right)^{\frac{\theta_2}{\theta_2-1}} + a_d \left(\frac{P_3}{a_d}\right)^{\frac{\theta_2}{\theta_2-1}} \right]^{-\frac{1}{\theta_2}} b \quad (\text{A17a})$$

$$L_{2,j,s} =$$

$$\left(\frac{w_s}{a_s}\right)^{\frac{1}{\theta_2-1}} \left[a_u \left(\frac{w_u}{a_u}\right)^{\frac{\theta_2}{\theta_2-1}} + a_s \left(\frac{w_s}{a_s}\right)^{\frac{\theta_2}{\theta_2-1}} + a_d \left(\frac{P_3}{a_d}\right)^{\frac{\theta_2}{\theta_2-1}} \right]^{-\frac{1}{\theta_2}} b \quad (\text{A17b})$$

$$Q_{3,j} =$$

$$\left(\frac{P_3}{a_d}\right)^{\frac{1}{\theta_2-1}} \left[a_u \left(\frac{w_u}{a_u}\right)^{\frac{\theta_2}{\theta_2-1}} + a_s \left(\frac{w_s}{a_s}\right)^{\frac{\theta_2}{\theta_2-1}} + a_d \left(\frac{P_3}{a_d}\right)^{\frac{\theta_2}{\theta_2-1}} \right]^{-\frac{1}{\theta_2}} b \quad (\text{A17c})$$

Substituting the conditional factor demand functions of (A17a) through (A17c), as well as a_u , a_s , a_d , and b into the cost function (A11) yields the minimum cost function.

$$C_{2,j} = C_{2f,j} +$$

$$\left[v_{2,u}^{\frac{1}{1-\theta_2}} \left(\frac{w_u}{\kappa_{2,u}} \right)^{\frac{\theta_2}{\theta_2-1}} + v_{2,s}^{\frac{1}{1-\theta_2}} \left(\frac{w_s}{\kappa_{2,s}} \right)^{\frac{\theta_2}{\theta_2-1}} + v_{2,d}^{\frac{1}{1-\theta_2}} \left(\frac{P_3}{\kappa_{2,d}} \right)^{\frac{\theta_2}{\theta_2-1}} \right]^{\frac{\theta_2-1}{\theta_2}} \frac{q_{2,j}}{\kappa_{2,n}}$$

To simplify notations, I define

$$\delta_{2,j} = v_{2,j}^{\frac{1}{1-\theta_2}} \text{ for } j = u, s, d, \quad \lambda_{2,j} = \frac{1}{\kappa_{2,j}} \text{ for } j = u, s, d, n \text{ and } \phi_2 = \frac{\theta_2}{\theta_2-1}$$

The minimum cost function can be rewritten as

$$C_{2,j} = C_{2f,j} + \left[\delta_{2,u} (\lambda_{2,u} w_u)^{\phi_2} + \delta_{2,s} (\lambda_{2,s} w_s)^{\phi_2} + \delta_{2,d} (\lambda_{2,d} P_3)^{\phi_2} \right]^{\frac{1}{\phi_2}} \lambda_{2,n} q_{2,j} \quad (17)$$

The conditional factor demand functions in terms of the cost function result by Shepard's Lemma as the derivative of the minimum cost function with respect to the factor price.

$$L_{2,j,k} = L_{2f,j,k} + \delta_{2,k} \lambda_{2,k}^{\phi_2} w_k^{\phi_2-1} \Theta^{\frac{1-\phi_2}{\phi_2}} \lambda_{2,n} q_{2,j} \text{ for } k = u, s \quad (18)$$

$$Q_{3,j} = \delta_{2,d} \lambda_{2,d}^{\phi_2} P_3^{\phi_2-1} \Theta^{\frac{1-\phi_2}{\phi_2}} \lambda_{2,n} q_{2,j} \quad (19)$$

$$\text{with } \Theta = \left[\delta_{2,u} (\lambda_{2,u} w_u)^{\phi_2} + \delta_{2,s} (\lambda_{2,s} w_s)^{\phi_2} + \delta_{2,d} (\lambda_{2,d} P_3)^{\phi_2} \right]$$

Profit maximization yields supply of the j -th variety of the luxury good. Firm j 's profit function is

$$\Pi_{2,j} = p_{2,j} q_{2,j} - C_{2,j} \quad (\text{A18})$$

The first-order condition is

$$\frac{\partial \Pi_{2,j}}{\partial q_{2,j}} = \frac{\partial p_{2,j}}{\partial q_{2,j}} q_{2,j} + p_{2,j} - \frac{\partial C_{2,j}}{\partial q_{2,j}} = 0 \quad (\text{A19})$$

Rearranging terms

$$p_{2,j} \left(\frac{\partial p_{2,j}}{\partial q_{2,j}} \frac{q_{2,j}}{p_{2,j}} + 1 \right) = \frac{\partial C_{2,j}}{\partial q_{2,j}} \quad (\text{A20})$$

From equation (4) the own-price elasticity of demand for q_{2j} can be derived as

$$\left| \frac{\partial q_{2,j}}{\partial p_{2,j}} \frac{p_{2,j}}{q_{2,j}} \right| = \frac{1}{\sigma} \quad (\text{A21})$$

Strictly speaking, equation (A21) holds only under the assumption that the marginal effect of a price change in q_{2j} on the price index for the aggregate consumption good is zero.²³

Substituting the own-price elasticity into the first-order condition.

$$p_{2,j} \left(1 - \frac{1}{\sigma} \right) = \frac{\partial C_{2,j}}{\partial q_{2,j}} \quad (\text{A22})$$

²³ This is a standard assumption in the literature that was first introduced by Krugman and Helpman (1985: 119). Monopolistic competition assumes a large number of firms producing variants of the differentiated good. In this case, a change in the price of a single firm will not change the aggregate price index by much. The effect can be thought negligible.

Using the parameter of differentiation from the aggregation function for the differentiated luxury good ρ , the implicit supply function for the j -th variety of the luxury good can be written as a mark-up over marginal costs.

$$p_{2,j} = \frac{1}{\rho} \left[\delta_{2,u} (\lambda_{2,u} w_u)^{\phi_2} + \delta_{2,s} (\lambda_{2,s} w_s)^{\phi_2} + \delta_{2,d} (\lambda_{2,d} P_3)^{\phi_2} \right]^{\frac{1}{\phi_2}} \lambda_{2,n} \quad (22)$$

The number of firms producing the differentiated luxury good is determined from the zero-profit condition: Additional firms will enter the markets, as long as profits are positive. Firms will drop out of the markets, when profits are negative. Hence, in equilibrium,

$$\Pi_{2,j} = p_{2,j} q_{2,j} - C_{2,j} = 0 \quad (23)$$

holds.²⁴

²⁴ The number of firms n enters the zero-profit condition through equation (4) for the utility maximizing demand for the luxury good.

Appendix 3 – Parameters and Simulation Results

Appendix 3.1 – Parameters and Shocks

Table A1 – Individual Preference Parameters and Population

	Stone-Geary Preferences		Cobb-Douglas Preferences
	Flexible Labor Market	Rigid Labor Market	
α	0.9	0.9	$\alpha_{\text{reference}}$
β_1	0.25	0.15	0
β_2	0	0	0
ρ	0.8	0.8	0.8
V_u	16000	16000	16000
V_s	14000	14000	14000

Table A2 – Technology Parameters Excluding Technical Change

	Basic Good	Luxury Good	Service
ϕ_i	0.5	0.5	0.5
v_{ju}	0.6	0.1	0.9
v_{js}	0.4	0.5	0.1
v_{jd}	–	0.4	–
μ	–	0.8	–
$L_{if,u}$	–	0.5	0.5
$L_{if,s}$	–	1	1

Table A3 – Technical Change Parameters^a

	Basic Good	Luxury Good	Service
$\lambda_{j,u}$	1 / 0.9	1 / 0.9	1 / 0.9
$\lambda_{j,s}$	1 / 0.9	1 / 0.9	1 / 0.9
$\lambda_{j,d}$	—	—	1 / 0.9
$\lambda_{j,a}$	1 / 0.9	1 / 0.9	1 / 0.9

^aReference scenario / shock.

Appendix 3.2 – Flexible Labor Markets

Table A4 – Technology Shocks under Stone-Geary Preferences

	Reference	Unskilled Specific	Skilled Specific	Neutral	Service Specific
Skilled Wage	0.77	0.85	0.80	0.89	0.77
Unskilled Wage	0.33	0.32	0.36	0.35	0.33
Relative Wage: Skilled/Unskilled	2.31	2.67	2.21	2.55	2.30
Aggregate Skilled Share	0.47	0.47	0.47	0.47	0.47
Skilled Share Basic Good	0.35	0.34	0.34	0.34	0.35
Skilled Share Luxury Goods	0.62	0.62	0.62	0.62	0.62
Skilled Share Intermediate Services	0.66	0.66	0.66	0.66	0.66
Aggregate Skilled Wage Share	0.67	0.70	0.66	0.69	0.67
Skilled Wage Share Basic Good	0.55	0.58	0.54	0.57	0.55
Skilled Wage Share Luxury Good	0.79	0.81	0.78	0.80	0.79
Skilled Wage Share Service	0.82	0.84	0.81	0.83	0.82
Expenditure Share Luxury Goods	0.48	0.50	0.50	0.53	0.48
Service Share in Luxury Goods	0.24	0.24	0.24	0.23	0.23
Output Basic Good	8354.02	8457.44	8439.81	8554.14	8353.67
Output Luxury Good per Variety	2.87	2.95	3.12	3.31	2.95
Output Service per Variety	3.64	3.70	3.96	4.04	3.64
Number of Firms Luxury Goods	1649.04	1699.29	1734.31	1782.38	1649.20
Number of Firms Service	392.55	405.05	410.21	408.05	379.36
GDP	16040.20	17074.40	16898.10	18041.40	16036.70

Table A5 – Technology Shocks under Cobb-Douglas Preferences

	Reference	Unskilled Specific	Skilled Specific	Neutral	Service Specific
Skilled Wage	0.77	0.83	0.78	0.85	0.77
Unskilled Wage	0.33	0.33	0.37	0.37	0.33
Relative Wage: Skilled/Unskilled	2.31	2.53	2.11	2.30	2.30
Aggregate Skilled Share	0.47	0.47	0.47	0.47	0.47
Skilled Share Basic Good	0.35	0.35	0.35	0.35	0.35
Skilled Share Luxury Goods	0.62	0.63	0.62	0.62	0.62
Skilled Share Intermediate Services	0.66	0.67	0.66	0.66	0.66
Aggregate Skilled Wage Share	0.67	0.69	0.65	0.67	0.67
Skilled Wage Share Basic Good	0.55	0.58	0.53	0.55	0.55
Skilled Wage Share Luxury Good	0.79	0.81	0.78	0.79	0.79
Skilled Wage Share Service	0.82	0.83	0.81	0.82	0.82
Expenditure Share Luxury Goods	0.48	0.48	0.48	0.48	0.48
Service Share in Luxury Goods	0.24	0.24	0.24	0.23	0.23
Output Basic Good	8354.02	8836.28	8750.50	9280.45	8352.40
Output Luxury Good per Variety	2.87	2.94	3.10	3.28	2.95
Output Service per Variety	3.64	3.70	3.96	4.04	3.64
Number of Firms Luxury Goods	1649.04	1626.55	1672.74	1649.46	1649.46
Number of Firms Service	392.55	388.77	396.50	379.42	379.42
GDP	16040.20	16966.10	16801.40	17819.00	16037.10

Appendix 3.3 – Rigid Labor Markets:

Unions with Stone-Geary Utility Function

Table A6 – Technology Shocks under Stone-Geary Preferences

	Reference	Unskilled Specific	Skilled Specific	Neutral	Service Specific
Skilled Wage	0.77	0.84	0.80	0.88	0.77
Unskilled Wage	0.33	0.33	0.36	0.35	0.33
Relative Wage: Skilled/Unskilled	2.32	2.59	2.22	2.50	2.32
Aggregate Unemployment Rate	0.09	0.09	0.07	0.07	0.10
Skilled Unemployment Rate	0.05	0.05	0.03	0.03	0.06
Unskilled Unemployment Rate	0.13	0.13	0.11	0.10	0.13
Unemployment Benefits Tax	0.05	0.05	0.04	0.03	0.05
Aggregate Skilled Share	0.49	0.49	0.49	0.49	0.49
Skilled Share Basic Good	0.35	0.35	0.34	0.34	0.35
Skilled Share Luxury Goods	0.62	0.62	0.62	0.62	0.62
Skilled Share Services	0.66	0.66	0.66	0.66	0.66
Aggregate Skilled Wage Share	0.69	0.71	0.68	0.70	0.69
Skilled Wage Share Basic Good	0.55	0.58	0.54	0.56	0.55
Skilled Wage Share Luxury Good	0.79	0.81	0.78	0.80	0.79
Skilled Wage Share Service	0.82	0.84	0.81	0.83	0.82
Expenditure Share Luxury Goods	0.56	0.57	0.57	0.59	0.56
Service Share in Luxury Goods	0.24	0.24	0.24	0.23	0.23
Output Basic Good	6554.19	6761.10	6780.19	7012.28	6550.19
Output Luxury Good per Variety	2.88	2.96	3.13	3.32	2.96
Output Service per Variety	3.64	3.70	3.96	4.04	3.64
Number of Firms Luxury Goods	1761.08	1798.11	1867.39	1899.58	1757.38
Number of Firms Service	417.03	426.46	439.09	432.46	402.19
GDP	14770.90	15805.50	15901.00	17061.40	14751.00

Table A7 – Technology Shocks under Cobb-Douglas Preferences

	Reference	Unskilled Specific	Skilled Specific	Neutral	Service Specific
Skilled Wage	0.77	0.83	0.79	0.86	0.77
Unskilled Wage	0.33	0.33	0.37	0.37	0.33
Relative Wage: Skilled/Unskilled	2.32	2.52	2.15	2.35	2.32
Aggregate Unemployment Rate	0.09	0.09	0.07	0.07	0.10
Skilled Unemployment Rate	0.05	0.05	0.04	0.03	0.06
Unskilled Unemployment Rate	0.13	0.12	0.11	0.10	0.13
Unemployment Benefits Tax	0.05	0.05	0.04	0.03	0.05
Aggregate Skilled Share	0.49	0.49	0.49	0.49	0.49
Skilled Share Basic Good	0.35	0.35	0.35	0.35	0.35
Skilled Share Luxury Goods	0.62	0.63	0.62	0.62	0.62
Skilled Share Services	0.66	0.67	0.66	0.66	0.66
Aggregate Skilled Wage Share	0.69	0.71	0.67	0.69	0.69
Skilled Wage Share Basic Good	0.55	0.58	0.53	0.56	0.55
Skilled Wage Share Luxury Good	0.79	0.81	0.78	0.79	0.79
Skilled Wage Share Service	0.82	0.83	0.81	0.82	0.82
Expenditure Share Luxury Goods	0.56	0.56	0.56	0.56	0.56
Service Share in Luxury Goods	0.24	0.24	0.24	0.23	0.23
Output Basic Good	6554.19	6994.33	7024.82	7519.65	6545.76
Output Luxury Good per Variety	2.88	2.95	3.12	3.30	2.96
Output Service per Variety	3.64	3.70	3.96	4.04	3.64
Number of Firms Luxury Goods	1761.08	1755.91	1819.58	1812.03	1758.27
Number of Firms Service	417.03	417.08	428.52	413.74	402.38
GDP	14770.90	15762.90	15831.60	16946.80	14751.90

Appendix 3.4 – Rigid Labor Markets:

Union for Skilled and Constant Relative Wages

Table A8 – Technology Shocks under Stone-Geary Preferences

	Reference	Unskilled Specific	Skilled Specific	Neutral	Service Specific
Skilled Wage	0.72	0.75	0.76	0.80	0.72
Unskilled Wage	0.36	0.38	0.38	0.40	0.36
Relative Wage: Skilled/Unskilled	2.00	2.00	2.00	2.00	2.00
Aggregate Unemployment Rate	0.13	0.15	0.10	0.12	0.13
Skilled Unemployment Rate	0.06	0.06	0.04	0.04	0.07
Unskilled Unemployment Rate	0.19	0.22	0.15	0.19	0.19
Unemployment Benefits Tax	0.07	0.08	0.05	0.06	0.07
Aggregate Skilled Share	0.50	0.52	0.50	0.51	0.50
Skilled Share Basic Good	0.37	0.38	0.35	0.37	0.37
Skilled Share Luxury Goods	0.63	0.64	0.63	0.63	0.63
Skilled Share Services	0.68	0.68	0.67	0.68	0.68
Aggregate Skilled Wage Share	0.67	0.68	0.66	0.68	0.67
Skilled Wage Share Basic Good	0.54	0.55	0.52	0.54	0.54
Skilled Wage Share Luxury	0.78	0.78	0.77	0.78	0.78
Good					
Skilled Wage Share Service	0.81	0.81	0.80	0.81	0.81
Expenditure Share Luxury Goods	0.54	0.55	0.57	0.57	0.54
Service Share in Luxury Goods	0.24	0.24	0.24	0.23	0.23
Output Basic Good	6416.46	6524.84	6670.62	6786.69	6412.71
Output Luxury Good per Variety	2.86	2.93	3.12	3.28	2.94
Output Service per Variety	3.64	3.71	3.96	4.04	3.64
Number of Firms Luxury Goods	1708.34	1720.00	1829.94	1834.53	1705.00
Number of Firms Service	404.61	407.82	430.26	417.39	390.26
GDP	14082.30	14624.20	15353.10	15933.50	14063.60

Table A9 – Technology Shocks under Cobb-Douglas Preferences

	Reference	Unskilled Specific	Skilled Specific	Neutral	Service Specific
Skilled Wage	0.72	0.75	0.76	0.80	0.72
Unskilled Wage	0.36	0.38	0.38	0.40	0.36
Relative Wage: Skilled/Unskilled	2.00	2.00	2.00	2.00	2.00
Aggregate Unemployment Rate	0.13	0.15	0.10	0.12	0.13
Skilled Unemployment Rate	0.06	0.06	0.04	0.04	0.07
Unskilled Unemployment Rate	0.19	0.22	0.15	0.19	0.19
Unemployment Benefits Tax	0.07	0.08	0.05	0.06	0.07
Aggregate Skilled Share	0.50	0.52	0.50	0.51	0.50
Skilled Share Basic Good	0.37	0.38	0.35	0.37	0.37
Skilled Share Luxury Goods	0.63	0.64	0.63	0.63	0.63
Skilled Share Services	0.68	0.68	0.67	0.68	0.68
Aggregate Skilled Wage Share	0.67	0.68	0.66	0.68	0.67
Skilled Wage Share Basic Good	0.54	0.55	0.52	0.54	0.54
Skilled Wage Share Luxury Good	0.78	0.78	0.77	0.78	0.78
Skilled Wage Share Service	0.81	0.81	0.80	0.81	0.81
Expenditure Share Luxury Goods	0.54	0.55	0.57	0.57	0.54
Service Share in Luxury Goods	0.24	0.24	0.24	0.23	0.23
Output Basic Good	6416.46	6524.84	6670.62	6786.69	6412.71
Output Luxury Good per Variety	2.86	2.93	3.12	3.28	2.94
Output Service per Variety	3.64	3.71	3.96	4.04	3.64
Number of Firms Luxury Goods	1708.34	1720.00	1829.94	1834.53	1705.00
Number of Firms Service	404.61	407.82	430.26	417.39	390.26
GDP	14082.30	14624.20	15353.10	15933.50	14063.60

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