Labor Mobility, Household Production, and the Dutch Disease

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Abstract

This paper studies a model of Dutch disease with learning by doing and household production. Only women work in the households. We compare economies with mobile labor and economies with gender specific sectors. In the latter economy, in addition to working in the household, women work in either the traded or the non-traded sector, and men allocate all their labor to the sector not occupied by women. The effect of enhanced natural resource abundance on factor allocation, the real exchange rate, wage rates, production, and growth are worked out for each case. Our analysis suggests that labor mobility and differences in how gender is grouped across sectors play a role in how natural resource abundance impacts economic performance.

Key Words: Dutch Disease, Endogenous Growth, Household Production, Segmented Labor Markets, Gender Wage Differentials

JEL Classification Codes: F35, F43, J22, J62, 041

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1 Introduction

Despite substantial efforts to reveal empirically the nature of how natural resource rents interact with economic development, it appears that no definite answers can be given to whether such rents are a blessing or a curse.[1] Earlier literature on the Dutch disease[2] depicts a negative relationship between resource earnings and productivity levels (see in particular van Wijnbergen 1984; Krugman 1987; Sachs and Warner 1995; and Gylfason et al. 1997 in the learning by doing context) and economic growth (Sachs and Warner 1995; and Gylfason et al. 1997). In contrast, Torvik (2001) proposes a Dutch disease model in which variation in sectoral learning by doing effects and spillover rates explains variation in how natural resources impact sectoral productivity. In this model, natural resources have no impact upon the long-term growth rate.

Generally, in these models labor moves flexibly between the traded and the non-traded sector, and the labor supply is exogenously given and constant. Behind these approximations lies an assumption about perfect labor mobility and about inelastic labor supply. While these assumptions may apply to some economies, they clearly seem unrealistic for others. They ignore the possibility that societal structures in the labor market matter for how an economy responds to changes in natural resource earnings, which is precisely what the Dutch disease models seek to analyze. Nevertheless, aspects of labor mobility and labor supply are almost[3] completely neglected in the existing Dutch disease literature.

We pay special attention to two circumstances which motivate how this issue can

[1] The resource curse hypothesis receives support by a large body of empirical literature (Auty 1993, 2001; Sachs and Warner 1995, 1999, 2001 among others). Nevertheless, the notion of an unconditional curse is also questioned empirically (Larsen 2005; Sala-i-Martin et al. 2004; Stijns 2005; Ng 2006; Brunnschweiler and Bulte 2006). See Frederiksen (2007) for a survey of the recent empirical literature.

[2] The precise meaning of Dutch disease has evolved over time (consult Stevens (2003) for a review). Our paper belongs to the strand of literature that relates Dutch disease to learning by doing effects on productivity and growth.

[3] We know of two exceptions; both neoclassical models. Hoel (1981) analyzes a short run Dutch disease model, where labor is immobile. Hsieh et al. (1998) examine endogenous labor-leisure choices within a Dutch disease model.

be addressed. The first circumstance concerns gender-grouping of the labor market. Gender-based occupational segregation, which has been shown to be a worldwide phenomenon, describes the situation in which labor markets are divided on the basis of gender (Anker 1998). Occupational segregation can be explained by social and cultural barriers that leads to labor market immobility, and, consequently, to a reduction in the economy's ability to adjust to change. Since it is precisely the economy's ability to adjust to change - in the form of a increased resource rents - which leads to the Dutch disease, occupational segregation presumably matters in understanding Dutch disease symptoms.

The second circumstance concerns household production. Household production supports the lives of most families; yet a person engaged in production for household use is not usually regarded as belonging to the labor force. Endogenous labor supply decisions, however, also influence how the economy adjusts to changes in resource earnings.

Therefore, we add a household sector to an economy, which is otherwise described by a Dutch disease model with learning by doing effects. We consider labor in the household a heterogeneous factor in production in that male labor is not productive. With respect to production in the two other sectors, the traded and the non-traded sector, we consider first labor as a homogenous factor of production, but barriers, such as stigma and customs, force men and women to work in separate sectors. Second, we consider an economy in which labor is completely mobile between the traded and the non-traded sector. In this scenario, the main departure from Torvik (2001) is the endogeneity of the female labor supply.

Our analysis demonstrates that labor market structures play a critical role in whether natural resources are a blessing or a curse; i.e., in the context of this paper, for production and growth. Slower economic growth rates in natural resource rich economies are explained by a movement of female labor into the household sector which does not contribute to overall economic growth. As we also show, whether women decrease their labor supply in response to increased natural resource intensity, in turn, depends on the gender-grouping of the labor market.

The paper is organized as follows. Next, we provide background information to support our analysis of the labor market. Section 3 presents the model, and equilibrium outcomes are explained in section 4. Section 5 presents a resource impact analysis. In particular, we analyze the link between labor market structure and the Dutch disease. Section 6 provides concluding remarks.

2 Background

Men's and women's labor market patterns diverge. Among other things, this divergence is manifested as gender-differences in occupations: "Occupational segregation by sex[4] is extensive in every region, at all economic development levels, under all political systems, and in diverse religious, social and cultural environments. It is one of the most important and enduring aspects of labour markets around the world" (Anker 1997, 315).

Explanations and theories of occupational segregation are numerous.[5] Anker (1998) distinguishes three categories: neoclassical, segmentation, and non-economic theories. Neoclassical theories typically explain occupational segregation by gender-differences in preferences, or in human capital. If women are less educated than men, for instance because women spend more time in the household, they will work in occupations that requires lower levels of education. Segmentation theories, on the other hand, argue that so-called barriers, which could be institutional, exist between segments of the economy. The idea is that each sector may function according to neoclassical theory, but barriers prevent interaction between sectors. Typically, one of the sectors is the well paid, "primary," or male dominated sector, whereas the other sector is the less attractive, "secondary," or female dominated, sector. Finally, non-economic explanations involve social norms and cultural restrictions. A classical example is *purdah*, which forbids women in some Islamic cultures to interact with male strangers in public (Anker 1998). Goldin (1995) argues that

[4] Often, the literature distinguishes between "sex" and "gender." The term "sex" refers to biology, and the term "gender" to differences that are learned on the basis of cultural or social norms. The current paper, however, uses the terms "sex" and "gender" interchangeably.

[5] See, e.g., Leontaridi (1998) for a review of the literature.

low-income societies stigmatize the husbands of women who perform paid work.

The extent of gender-segregation in occupations varies from region to region. Sanday (1981, 80) notes that: "Sexual separation is so extreme in some societies that almost all work activities are defined as either male or female, with the result that the sexes form sexual ghettos." At the same time, Sanday finds considerable diversity in the cultural patterning of work. Also Boserup (1970) documents wide variations across Africa, Asia, and Latin America in the representation of women in agriculture, trade, and administration. Tasks considered male in one society are often allocated to women in others.

There are several ways to measure gender-based occupational segregation. Anker (1998) presents two,[6] among others, measures: the *index of dissimilarity* (ID) and *the representation ratio for women.* The ID measure is the most commonly used, but also criticized, index for measuring gender segregation of labor markets. It measures the sum over all occupations of the absolute differences between the proportion of all females and all males in each occupation divided by two, and hence it ranges from zero to one. The higher the ID, the higher the gender-based occupational segregation. Table 1 presents the ID in five regions of the world.

Table 1 Regional index of dissimilarity (ID)

	Region[a]				
	OECD	Middle East and North Africa	Asia/Pacific	Other Developing	Transition Economies
ID	0.600	0.672	0.492	0.629	0.593

Source: Anker (1998).

[a] In all, 41 countries are included in the data.

We observe a variation in the degree of gender segregation across regions. Gender segregation is highest in the Middle East and North Africa region, and lowest in the Asia/Pacific region. We also note that the OECD region has considerable segregation.

[6] We refer to Anker (1998, ch. 5) for a thorough and technical explanation of the different measures.

The pattern of gender segregation in table 1 is in conformity with women's representation ratios across six occupational groups, all non-agricultural, which are illustrated in table 2. The representation ratio is the percentage female in an occupational group divided by the average percentage female for the non-agricultural labor force[7] as a whole. A value greater than one implies that women are overrepresentented (and a value less than one implies that women are underrepresentated) relative to their overall share of the non-agricultural labor force.

Table 2 Representation Ratios for Women for Six Occupational Groups

Region[a]	Occupational Group					
	Prof. and technical	Admin. and managerial	Clerical	Sales	Services	Prod.
OECD	1.17	0.51	1.61	1.24	1.51	0.37
Middle East and North Africa	2.43	0.46	1.85	0.28	1.25	0.33
Asia/Pacific	1.35	0.34	0.95	1.02	1.42	0.74
Latin America and Caribbean	1.21	0.58	1.37	1.25	1.53	0.43
Africa	1.15	0.39	1.31	1.47	1.13	0.51

Source: Anker (1998).

[a] In all, 56 countries are included in the data.

Table 2 reveals variation across regions in the representation of women.[8] In general, however, there are two occupational groups in which women are underrepresented: administrative and managerial occupations and production. The administrative and managerial occupational group is a small group and employs roughly four percent of the labor force. In contrast, production is a large occupational group and employs about 33-48 percent of the labor force.

Within the two male dominated occupational groups: administrative and managerial occupations and production, men typically hold jobs as government administrators and various types of construction workers.

[7]In Anker's (1998) representation ratio estimates, agricultural occupations are excluded from the data. The reason is methodological problems of measuring correctly and consistently agricultural employment, as a large share of agricultural employment is incorporated in household work; especially, in developing countries.

[8]In addition, which is not shown in the table, there is also great variation within regions (Anker 1998).

Not surprisingly, women are overrepresented in the traditional female occupations such as services, clerical, and sales, with the exception of the Middle East and North Africa region, in which women are strongly underrepresented in sales. Women's underrepresentation in sales in this region may be explained by the above mentioned tradition of *purdah*. Women are generally also overrepresented in the professional and technical group. This can be ascribed to their larger representation in jobs such as teachers and nurses.

Another aspect of the differences in men's and women's labor market patterns relates to the household sector in that households, worldwide, are operated mainly by female labor. In developing countries, despite variations from rural to urban households, as some household work, or subsistence activities, which can be performed in rural areas cannot be carried out in urban surroundings, women use a large share of their labor endowments in the household (Boserup 1970). Newman (2002) finds that in Ecuador, men spend on average 62 minutes per day in the household, whereas women spend as much as 327 minutes. In Pakistan, Fafchamps and Quisumbing (2003) find that women do 80-90 percent of all household chores. Also women in developed countries use a substantial part of their labor resources in the household. Freeman and Schettkat (2005) find, among seven developed countries,[9] that women, on a daily work day, spend on average 203 minutes, whereas men spend only 93 minutes, in the home.

In the context of a Dutch disease model, gender-differences in labor market patterns form an additional, a societal, dimension. As pointed out in, e.g., Torvik (2001) and Isham et al. (2005), there is great variation across nations in what sectors produce exported, traded goods, and what sectors produce domestic, non-traded, goods. For instance, some countries may export manufactured goods, whereas other countries export agricultural goods. Based on the labor market patterns presented above, it is therefore likely, that, besides this type of variation, there is also variation across countries in whether traded and non-traded sectors are "male" or "female"

[9] Freeman and Schettkat (2005) study Canada, Netherlands, Norway, UK, US, Italy, and Austria.

occupations.[10]

Thus, in order to study how different combinations of gender and sectors, or what we could refer to as societal structures, effect the economy's adjustment pattern to a change in natural resource rents, this paper provides both an analysis of a gender segmented labor market, and of a labor market in which traded and non-traded sectors are divided equally among men and women. In each case, however, only women work in the household.

3 The Model

We use a non-overlapping generations model with perfect competition. The economy consists of three sectors. Sector 1 is a non-traded sector, sector 2 is a traded sector, and sector 3 is a household sector. We refer to the traded and the non-traded sectors as the formal sectors since output is sold and purchased in the market place. Output from the household sector is completely consumed within the household in which it is produced. All sectors employ labor supplied by household members, and, specifically, the household sector uses only female labor.

Households are formed by two individuals, a woman and a man. Both live for one period, and both have an endowment of $L > 0$ units of labor. The number of households remains constant, households are identical, and we normalize the number of households to equal one.

3.1 Traded and Non-traded Production

Also producers within each of the traded and the non-traded sectors are identical. For the representative producer, production occurs with labor, l_t, and a fixed factor as input. Production in the specific factors model has constant returns to scale,[11] and we consider one firm within each sector. Growth is fuelled by learning by doing

[10] Of course, this hypothesis would be strengthened considerably by a detailed study of separate countries. For now, this is beyond the scope of this paper and left for future investigation. Some preliminary results in this direction can be found in Ross (2006).

[11] Specific factor models often assume that one sector uses capital specific to that sector, and another uses land, both fixed in supply, and that labor is mobile. See, e.g., Matsuyama (1992).

and evolves over time as a by-product of production. Let x_{st} denote output in the $s = (1, 2)$ sector at time t; thus,

$$x_{1t} = H_{1t} {l_{1t}}^{\alpha}, \quad (1)$$

$$x_{2t} = H_{2t} {l_{2t}}^{\beta}, \quad (2)$$

where $H_{s0} > 0$, H_{st} is a positive productivity term, which can vary between the two sectors, and $0 < \alpha < 0$ and $0 < \beta < 0$ are the labor shares in production.

Earlier literature on the Dutch disease has traditionally attributed productivity growth to the traded sector only; e.g., van Wijnbergen (1984) and Krugman (1987). Sachs and Warner (1995) introduce perfect spillover of learning by doing to the non-traded sector. We follow Torvik's (2001) approach and assume that learning by doing is generated in all formal sectors, and that intersectoral spillovers are positive in all directions. Let g_{st} denote growth rates of productivity in the s sector; then,

$$\frac{\dot{H}_{1t}}{H_{1t}} = g_{1t} = l_{1t} + \delta l_{2t}, \quad (3)$$

$$\frac{\dot{H}_{2t}}{H_{2t}} = g_{2t} = \delta l_{1t} + l_{2t}, \quad (4)$$

where $0 \leq \delta \leq 1$ is the spillover rate between sectors.[12] To simplify matters, the spillover rate from the non-traded sector to the traded sector equals that from the traded sector to the non-traded sector.[13] As workers from each formal sector interact in other places than at the workplace, even in a situation when labor is intersectorally immobile, technology diffusion can still occur.

Using the traded good[14] as *numeraire,* p_{1t} is the price of the non-traded good in terms of the traded good, i.e., the real exchange rate. The representative competitive producer within each sector employs factors in order to maximize profits, π_{st}, and takes as given output and input prices. Under perfect competition, profit

[12] Thus, within sectors, this model suffers from the often criticized permanent growth effect of scale.

[13] Torvik (2001) contains a rigorous analysis of different spillover rates.

[14] The price of the traded good is given as a given (world market) price, whereas prices on the non-traded good and the household good are determined within the model.

maximization leads to

$$\frac{\partial \pi_{1t}}{\partial l_{1t}} = p_{1t}\alpha \frac{x_{1t}}{l_{1t}} - w_{1t} = 0, \tag{5}$$

$$\frac{\partial \pi_{2t}}{\partial l_{2t}} = \beta \frac{x_{2t}}{l_{2t}} - w_{2t} = 0, \tag{6}$$

where w_{st} is the wage rate in sector $s = (1, 2)$. The firm's profits are maximized when the marginal product of labor equals the wage rate.

3.2 Natural Resources

The economy is endowed with natural resources. In every period t, the economy receives a return from the natural resource as an inflow, a revenue, R_t, which is given directly to the households. The revenue is a fixed fraction, $\xi \geq 0$, of the real income of man-made output in the formal sectors in terms of traded goods, y_t :

$$R_t = \xi y_t, \tag{7}$$

where $y_t = p_{1t}x_{1t} + x_{2t}$. We refer to ξ as the natural resource intensity. The revenue, R_t, varies with changes in output in either formal sector, but the revenue output ratio remains constant. Using this specification, we model the natural resource revenues as if they arrive as manna from heaven. An alternative interpretation is to think of R_t as inflows of foreign aid.[15]

3.3 Households and Household Production

Production in the household sector differs from formal production in that it purely takes female labor as input. Furthermore, productivity is constant[16] and does not interact with productivity in the formal sectors. Let x_{3t} denote output, so that

$$x_{3t} = {l_{3t}}^{\gamma}, \tag{8}$$

where $0 < \gamma \leq 1$.

[15] Similar ways of modeling of either a natural resource or foreign aid inflow are found in Chatterjee et al. (2003), Lesink and White (2001), Papyrakis and Gerlagh (2004), and Torvik (2001).

[16] Fafchamps and Quisumbing (2003) find a constant reallocation of household chores among women, which implies that household chores are easy to learn. Put differently, it seems there is no learning by doing effects which increase productivity in the household.

We assume that each family member has an equal weight in the family welfare function and identical preferences. In this case, we use a conventional unitary household model with household production. Preferences are defined over consumption of the non-traded good, c_{1t}; consumption of the traded good, c_{2t}; and consumption of the household good, z_t. For convenience, let the utility function, u, be given as

$$u(c_{1t}, c_{2t}, z_t) = \phi \ln(c_{1t}) + (1 - \phi) \ln(c_{2t}) + \mu \ln(z_t), \tag{9}$$

where $0 < \phi < 1$ and $\mu > 0$ are parameters. There are no savings or bequests in the economy, so household consumption equals household income at any period. Disposable household income is the sum of male and female earnings and the value of a natural resource revenue, R_t. Accordingly, the household maximizes utility given in (9) subject to

$$p_{1t}c_{1t} + c_{2t} = p_{1t}x_{1t} + x_{2t} + R_t, \tag{10}$$

$$p_{3t}z_t = p_{3t}x_{3t}, \tag{11}$$

$$l_t^f + l_{3t} = L, \text{ with } l_t^f \geq 0 \text{ and } l_{3t} \geq 0, \tag{12}$$

$$l_t^m = L, \tag{13}$$

by efficiently choosing c_{1t}, c_{2t}, and z_t, taking as given prices and the resource revenue, R_t. The shadow price of the household good relative to the price on the traded good is denoted p_{3t}, and labor supplies, l_t^f and l_t^m, are the female and male labor supply to the formal sectors respectively. Eq. (10) says that the household uses disposable income for consumption of the traded and the non-traded good, and (11) says that the household consumes all the household good which is produced within the household. Eq. (12) is the female labor endowment constraint and (13) its male counterpart.

The first order conditions from the utility maximization problem are given as

$$\frac{\phi}{1-\phi}\frac{c_{2t}}{c_{1t}} = p_{1t}, \tag{14}$$

$$\frac{\mu}{1-\phi}\frac{c_{2t}}{z_t} = p_{3t}, \tag{15}$$

$$\frac{\mu}{\phi}\frac{c_{1t}}{z_t} = \frac{p_{3t}}{p_{1t}}, \tag{16}$$

$$\frac{w_t^f}{\gamma(L-l_t^f)^{\gamma-1}} = p_{3t}, \tag{17}$$

where w_t^f denotes the wage rate in the sector(s) which employ(s) women.

The first three conditions, (14)-(16), are the standard conditions ensuring that the marginal rate of transformation between any two goods equals the marginal rate of substitution between the same two goods. Due to Cobb-Douglas preferences, budget shares are constant. The last condition, (17), says that the marginal value product of the labor in household production good equals the opportunity cost, the wage rate, in optimum.

4 Equilibrium

In equilibrium, firms earn zero marginal profits. Hence, from (5) and (6)

$$w_{1t}^* = p_{1t}^*\alpha H_{1t}{l_{1t}^*}^{\alpha-1}, \tag{18}$$

$$w_{2t}^* = \beta H_{2t}{l_{2t}^*}^{\beta-1}, \tag{19}$$

where a star denotes equilibrium levels.

The labor market clears for both male and female workers, which means

$$l_t^{m*} = L, \tag{20}$$

$$l_t^{f*} = L - l_{3t}^*, \tag{21}$$

as only women divide their labor between the household sector and a formal sector. The non-traded good market clears; i.e., consumption equals supply:

$$c_{1t}^* = x_{1t}^*,$$

and consumption of the household good equals production of the household good;

$$z_t^* = x_{3t}^*.$$

Using the shadow price of the household good, the resource constraint is

$$p_{1t}^* c_{1t}^* + c_{2t}^* + p_{3t}^* z_t^* = (1+\xi) y_t^* + p_{3t}^* x_{3t}^*, \tag{22}$$

as the traded good is the numeraire.

In order to evaluate income level effects, we also give

$$GDP_t^* = y_t^* + R_t^* = p_{1t}^* x_{1t}^* + x_{2t}^* + R_t^* = (1+\xi)(p_{1t}^* x_{1t}^* + x_{2t}^*), \tag{23}$$

where y_t^* is man-made output, and the last equality follows from (7).

4.1 Characterizing Three Economies

We study three template economies, or scenarios, which we refer to as *Men in Trade (MiT), Women in Trade (WiT),* and *Mobile Labor (ML)* respectively. In the two former economies, the labor market is completely segmented by sex. Men inelastically supply all labor to one sector,[17] whereas women face a trade-off between allocating labor to the household sector and a formal sector. In a *Mobile Labor* economy, male and female workers move freely between formal sectors.

In the following, we solve the model for each economy. As only the supply side of the model differs among the three labor market specifications, we begin by deriving the demand side.

From (22), the first order conditions from the household's utility maximization problem, (14)-(16), and the definition of y_t, the demand for the non-traded good can presented as

$$p_{1t} = \frac{\phi(1+\xi)}{1-\phi(1+\xi)} \frac{x_{2t}}{x_{1t}} = \frac{\phi(1+\xi)}{1-\phi(1+\xi)} \frac{H_{2t} {l_{2t}}^{\beta}}{H_{1t} {l_{1t}}^{\alpha}}, \tag{24}$$

where the last equality follows from (1) and (2). Likewise, the demand for the household good can be found as

$$p_{3t} = \frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{x_{2t}}{x_{3t}} = \frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{H_{2t} {l_{2t}}^{\beta}}{{l_{3t}}^{\gamma}}, \tag{25}$$

[17]Thus, the sector in which men work is treated as an "all-factors-specific" sector.

where the last equality follows from (2) and (8). We combine (24) and (25), since this expression becomes useful later, to obtain

$$p_{1t} = \frac{\phi}{\mu}\frac{x_{3t}}{x_{1t}}p_{3t} = \frac{\phi}{\mu}\frac{{l_{3t}}^{\gamma}}{H_{1t}{l_{1t}}^{\alpha}}p_{3t}. \tag{26}$$

We notice a constant term in (24), (25), and (26). This term reflects that budget shares are constant. Moreover, in (24) and (25) the constant involves the term $1+\xi$, which adjusts for that fact that a positive resource revenue inflow puts a wedge between consumption and production of the traded good. If the resource inflow is absent, the constant term in (24) and (25) is simply the relative budget shares given by the preferences.

Having laid out the demand side of the model, we now turn to the supply side for each scenario in order to characterize the equilibrium labor allocation.

4.1.1 Labor Allocation in the Men in Trade Economy

In a MiT economy, by (12) and (13), $l_t^f \equiv l_{1t}$, thus, $l_{1t} + l_{3t} = L$. Moreover, $l_t^m \equiv l_{2t}^* = L$ by definition. We use the labor allocation efficiency condition in (17) to derive the supply of the household good. By (18), since women work in the non-traded sector, (17) becomes:

$$p_{3t}^{MiT} = p_{1t}^{MiT}\frac{\alpha}{\gamma}H_{1t}(l_{1t})^{a-1}(L-l_{1t})^{1-\gamma}. \tag{27}$$

Equating (26) and (27), the female labor supply in equilibrium is derived as

$$l_1^{MiT}(\alpha,\gamma,\phi,\mu)^* = \left(\frac{1}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}+1}\right)L, \tag{28}$$

and, by the labor endowment constraint,

$$l_3^{MiT}(\alpha,\gamma,\phi,\mu)^* = \left(\frac{\frac{\mu}{\phi}\frac{\gamma}{\alpha}}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}+1}\right)L. \tag{29}$$

We observe that both the female labor allocation and the female labor supply are constant and independent of the resource intensity. Moreover, the higher the labor share in production within a sector, and the higher the budget share of its output, the greater the share of the labor endowment which is being allocated to that particular sector; i.e.,$\frac{\partial l_3^{MiT}(\cdot)^*}{\partial\alpha} < 0$, $\frac{\partial l_3^{MiT}(\cdot)^*}{\partial\phi} < 0$, $\frac{\partial l_3^{MiT}(\cdot)^*}{\partial\gamma} > 0$, and $\frac{\partial l_3^{MiT}(\cdot)^*}{\partial\mu} > 0$.

4.1.2 Labor Allocation in the Women in Trade Economy

In a *WiT* economy, women efficiently allocate their labor between the household and the traded sector. Therefore, by (12) and (13), $l_t^f \equiv l_{2t}$ and $l_{2t} + l_{3t} = L$. Men, by definition, inelastically supply labor to the non-traded sector; $l_t^m \equiv l_{1t}^* = L$.

Again we use the labor allocation efficiency condition in (17) to derive an expression for the supply of the household good. We apply (19) and find

$$p_{3t}^{WiT} = \frac{\beta}{\gamma} H_{2t}(l_{2t})^{\beta-1}(L - l_{2t})^{1-\gamma}. \tag{30}$$

By equating (25) and (30), the female labor supply to the traded sector in equilibrium is

$$l_2^{WiT}(\beta, \gamma, \phi, \mu, \xi)^* = \left[\frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1} \right] L, \tag{31}$$

and, using the labor endowment constraint, the female labor share used in the household sector is

$$l_3^{WiT}(\beta, \gamma, \phi, \mu, \xi)^* = \left[\frac{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta}}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1} \right] L. \tag{32}$$

To avoid corner solutions, we impose the following restriction on the natural resource intensity:

$$\xi < \frac{1-\phi}{\phi}.$$

When $\xi = \frac{1-\phi}{\phi}$, the inflow of resource revenues increase the demand for the non-traded good and the household good to an extent that all labor moves out of the traded sector until it shuts down. When $\xi > \frac{1-\phi}{\phi}$, there is no equilibrium as labor demand in the household sector exceeds the woman's labor endowment, L.

The woman's labor allocation depends on ξ, but it is constant for given levels of natural resource intensity. Like the *MiT* economy, women allocate more labor to the household at higher labor shares in the home sector and at higher budget shares of its output, and reversely for the formal sector in which they work; i.e. $\frac{\partial l_3^{WiT}(\cdot)^*}{\partial \beta} < 0$, $\frac{\partial l_3^{WiT}(\cdot)^*}{\partial \phi} > 0$, $\frac{\partial l_3^{WiT}(\cdot)^*}{\partial \gamma} > 0$, and $\frac{\partial l_3^{WiT}(\cdot)^*}{\partial \mu} > 0$.

4.1.3 Labor Allocation in the Mobile Labor Economy

In a *ML* economy (as in a *MiT* and *WiT* economy), the size of the labor force is the sum of female and male labor endowments minus female labor used in the household sector; i.e., $2L - l_{3t}$. Of this quantity, a share, η_t, is allocated to the non-traded sector, and the remaining share, $(1 - \eta_t)$, to the traded sector. Hence, $l_{1t} \equiv \eta_t(2L - l_{3t})$ and $l_{2t} \equiv (1 - \eta_t)(2L - l_{3t})$.

As in the standard Dutch disease model with mobile labor, the wage rates are identical across sectors in equilibrium. Equating (18) with (19), and applying (24), we find that

$$\eta(\xi)^* = \frac{1}{\frac{1-\phi(1+\xi)}{\phi(1+\xi)}\frac{\beta}{\alpha} + 1}. \tag{33}$$

Assuming $\xi < \frac{1-\phi}{\phi}$, it follows that $0 < \eta(\xi)^* < 1$.

In equilibrium, the marginal value product of labor used in household production equals the wage rate. Female labor used in household production, l_{3t}, can then be derived by combination of (17), (18), (26), and (33):

$$l_3^{ML}(\alpha, \gamma, \phi, \mu, \xi)^* = \left[\frac{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^*}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^* + 1}\right] 2L. \tag{34}$$

To avoid corner solutions, we need furthermore to assume that

$$\eta(\xi)^* < \frac{\phi}{\mu}\frac{\alpha}{\gamma}.$$

If $\eta(\xi)^* = \frac{\phi}{\mu}\frac{\alpha}{\gamma}$, the woman uses all her labor endowments, L, in the household, and if $\eta(\xi)^* > \frac{\phi}{\mu}\frac{\alpha}{\gamma}$ there is no equilibrium, since $l_3^{ML}(\xi)^*$ cannot exceed L.

By (34), we obtain

$$l_1^{ML}(\alpha, \gamma, \phi, \mu, \xi)^* = \eta(\xi)^* \left[\frac{1}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^* + 1}\right] 2L, \tag{35}$$

and

$$l_2^{ML}(\alpha, \gamma, \phi, \mu, \xi)^* = [1 - \eta(\xi)^*] \left[\frac{1}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^* + 1}\right] 2L. \tag{36}$$

Both female and male labor allocation depends on the natural resource intensity.

4.2 Static Equilibrium

Having characterized the equilibrium labor allocation, equilibrium values of all other variables can now be obtained. Insertion of equilibrium labor allocation in (24) gives p_{1t}^*, in (25) gives p_{3t}^*, and in (23) gives GDP_t^* in the respective economy. Likewise, wage rates can be derived from (18) and (19). We refer the reader to the Appendix A for this exercise.

As shown in the Appendix A, in all economies; *Men in Trade, Women in Trade,* and *Mobile Labor*, wage rates, GDP, and the shadow price of the household good grow that the same rate as productivity growth in the traded sector. The price of the non-traded good - the real exchange rate - grows at the ratio of productivity growth in the traded sector to the non-traded sector. In the following, we describe the dynamics for each economy.

4.3 Dynamics

There is zero learning by doing in the household, and we focus on the two differential equations given in (3) and (4). From these equations it is clear that, in general, output in one sector grows faster than output in the other. By (28), (31), and (34) we can rewrite (3) and (4) as

$$g_1^{MiT*} = \left(\frac{1}{\frac{\mu}{\phi}\frac{\gamma}{\alpha} + 1} + \delta \right) L, \tag{37}$$

$$g_2^{MiT*} = \left(\frac{\delta}{\frac{\mu}{\phi}\frac{\gamma}{\alpha} + 1} + 1 \right) L, \tag{38}$$

and,

$$g_1^{WiT}(\xi)^* = \left[1 + \frac{\delta}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)}\frac{\gamma}{\beta} + 1} \right] L, \tag{39}$$

$$g_2^{WiT}(\xi)^* = \left[\delta + \frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)}\frac{\gamma}{\beta} + 1} \right] L, \tag{40}$$

and,

$$g_1^{ML}(\xi)^* = \frac{1}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^*+1}\left\{\eta(\xi)^*+\delta[1-\eta(\xi)^*]\right\}2L, \quad (41)$$

$$g_2^{ML}(\xi)^* = \frac{1}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^*+1}\left\{\delta\eta(\xi)^*+[1-\eta(\xi)^*]\right\}2L, \quad (42)$$

for the three economies respectively. Productivity growth in either sector in either economy is constant. Moreover, when the learning by doing spillover across sectors is less than the direct effect; i.e., when $\delta < 1$, in the MiT economy

$$g_1^{MiT*} - g_2^{MiT*} = (\delta-1)\frac{\frac{\mu}{\phi}\frac{\gamma}{\alpha}}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}+1}L < 0, \quad (43)$$

whereas, in the WiT economy,

$$g_1^{WiT}(\xi)^* - g_2^{WiT}(\xi)^* = (1-\delta)\frac{\frac{\mu(1+\xi)}{1-\phi(1+\xi)}\frac{\gamma}{\beta}}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)}\frac{\gamma}{\beta}+1}L > 0. \quad (44)$$

Independently of how gender and sectors are combined, output in the sector that employs male labor grows faster than output in the sector that employs female labor. Hence, the asymptotic growth rate is given by the male sector. The reason is that as the woman uses a share of her labor endowments in household production, the direct effect of learning by doing generated by female labor is less than the direct effect of learning by doing generated by male labor. Thus, when spillover effects are only a fraction of the direct effects, productivity growth in the female sector is less than productivity growth in the male sector.

When spillover is perfect, in which case $\delta = 1$, from either of (3) and (4), we find that two sectors grow at the same rate. Specifically,

$$g^{MiT*} = \left(\frac{1}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}+1}+1\right)L, \quad (45)$$

$$g^{WiT}(\xi)^* = \left[1+\frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)}\frac{\gamma}{\beta}+1}\right]L. \quad (46)$$

In contrast, in a ML economy,

$$g_1^{ML}(\xi)^* - g_2^{ML}(\xi)^* = (1-\delta)\frac{2\eta(\xi)^*-1}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^*+1}2L > 0 \text{ if } \eta(\xi)^* > \frac{1}{2}. \quad (47)$$

Output in the sector which employs the largest share of the labor force grows faster than the other sector, and the asymptotic growth rate is given by this sector. When $\eta^* = \frac{1}{2}$, the two sectors grow at the same rate. The two sectors also grow at the same rate when spillovers are perfect, in which case, the growth rate is given as

$$g^{ML}(\xi)^* = \frac{1}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^* + 1} 2L. \tag{48}$$

Having solved the model and described the dynamics of the three economies, the next section analyzes the role of the natural resource intensity upon the performance in each economy.

5 Resource Impact

The Dutch disease is named after a sequence of reactions shown by the Dutch economy after discovery of large natural gas reserves in the Netherlands. Classical Dutch disease symptoms include appreciation of the real exchange rate, i.e., an increase in p_{1t}^*, and a decline in the share of the labor force employed in the traded sector whereby the economy's competitiveness with respect to imports is hurt. It is typically assumed that productivity is generated purely in the traded sector; thus, the long-run growth rate is also harmed. An exception to these results is found in Torvik (2001) where the real exchange rate depreciates in response to larger natural resource revenue flows, but the long-run growth rate is unaffected.

In the following, we analyze and discuss for each economy how it adjusts to a permanent change in ξ. We examine how the economy in general and female labor allocation in particular are affected.

5.1 Dutch Disease Symptoms in the MiT Economy

We begin by giving the following results:

Proposition 1. *Let $\xi \geq 0$. In a MiT economy, an increase in resource intensity, i.e., in ξ:*

(i) has no impact on female labor supply;

(ii) leads to appreciation of the real exchange rate;

(iii) increases women's wage rate relative to men's wage rate;

(iv) increases the man-made output and the GDP level; and,

(v) has no impact on productivity growth.

PROOF. See Appendix B.

These results diverge from the traditional Dutch disease result in one central respect: employment in the non-traded and traded sector remains unaffected as the resource intensity changes. The intuition is as follows: The higher the resource intensity, the larger the gap between production and consumption of the traded good. To keep budget shares constant, demand for the non-traded good increases, and the real exchange rate appreciates. This is the effect that traditionally shifts employment from the traded sector to the non-traded sector. In our model, however, we have an additional effect. Also demand for the household good increases and the shadow price of the household good appreciates.[18] Indeed, female labor allocation remains unaffected since demand and supply of the non-traded good and of the household good shift equally up. In the new equilibrium, only domestic output prices have changed.

As the wage rate in the non-traded sector depends upon the real exchange rate, despite the constant factor allocation, women's wage rate increases. The male wage rate, on the other hand, is unaffected by the change in the resource intensity since the price of the traded good is exogenous and male labor is immobile. Hence, if male wage rates initially are higher than female, the wage gap between men and women decreases.

Both man-made output and GDP levels increase since, besides a positive effect which arises from the resource itself, also a positive effect on output in the non-traded sector arises from the appreciation of the real exchange rate. Productivity growth remains unaffected as the labor allocation and labor supply determine learning by doing. Hence, in a MiT economy, higher resource intensity merely implies

[18] To see this, by (50) $\frac{\partial p_{3t}^{MiT}(\xi)^*}{\partial \xi} = H_{2t} L^{\beta-\gamma} \left(\frac{\frac{\mu}{\phi}\gamma+\alpha}{\frac{\mu}{\phi}\gamma} \right)^{\gamma} \frac{\mu}{[1-\phi(1+\xi)]^2} > 0$.

positive level effects.

5.2 Dutch Disease Symptoms in the WiT Economy

Again, we begin by stating the following results:

PROPOSITION 2. *Let* $0 \leq \xi < \frac{1-\phi}{\phi}$. *In the WiT economy, an increase in resource intensity, i.e., in* ξ*:*
(i) decreases female labor supply;
(ii) leads to appreciation of the real exchange rate;
(iii) increases the men's and women's wage rate, but the female to male wage ratio decreases;
(iv) increases man-made output and the GDP level; and,
(v) causes productivity growth to decline.

PROOF. See Appendix B.

Similar to the *MiT* economy, as resource intensity increases also demand for the household good and for the non-traded good increases. Male workers cannot supply more labor to the non-traded sector, but, to meet demand for the household good, women withdraw from the labor force and allocate more labor for household use. The *WiT* economy therefore exhibits the classical Dutch disease symptom of contraction of the traded sector. In our model, however, the reason is that the female labor force participation declines; not that female labor moves to the non-traded sector.

As the woman withdraws a share of her labor endowments from the labor force, production of the traded good goes down. To keep budget shares constant, demand for the non-traded good also declines. On the other hand, higher resource intensity imposes a larger gap between production and consumption of the traded good, which, in turn, increases the price of the non-traded good. As the latter effect is stronger, the real exchange rate appreciates.

Both men's and women's wage rate increase. The female wage rate increases as the marginal productivity of female labor goes up concurrently with the woman moving out of the labor force, whereas the male wage rate increases as the real exchange rate appreciates.

A positive level effect on man-made output arises from the appreciation of the real exchange rate, whereas a negative level effect arises from the contraction of the traded sector, and the former effect dominates. In addition, the GDP level benefits also from the resource revenue itself.

There is no ambiguity in the growth effects. When learning by doing spillovers are less than their direct effects ($\delta < 1$), productivity growth in the traded sector is relatively more damaged by increased resource intensity than productivity growth in the non-traded sector. Since productivity growth is already higher in the non-traded sector (the male sector), this means that the productivity gap between the two formal sectors increases further with higher levels of resource inflows; i.e., the productivity ratio, $\frac{H_{2t}}{H_{1t}}$, falls. Hence, the real exchange rate appreciates at a rate faster than prior to the increase in natural resource intensity.

In contrast, when spillovers are perfect ($\delta = 1$), the growth rate is equally affected in the two sectors. In this case, p_{1t}^{WiT*} is constant, and the only resource impact on the real exchange rate is a level effect.

Recall that wage rates, the GDP level, and the shadow price of the household good all grow at the same rate as productivity growth in the traded sector, g_2^{WiT}. Therefore, these variables all grow at slower rates in response to the increase in natural resource intensity.

5.3 Dutch Disease Symptoms in the ML Economy

When labor is mobile, in addition to women's labor supply, we also analyze how the labor force dispersion between the formal sectors is influenced.

PROPOSITION 3. *Let* $0 \leq \xi < \frac{1-\phi}{\phi}$ *and* $\eta(\xi)^* < \frac{\phi}{\mu}\frac{\alpha}{\gamma}$. *In the ML economy, an increase in resource intensity, i.e., in* ξ*:*
(i.a) increases the share of the labor force employed in the non-traded sector, but decreases female labor supply;

(i.b) increases employment in the non-traded sector;

(ii) has an ambiguous effect on the real exchange rate;

(iii) increases the wage rate;

(iv) has an ambiguous effect on the man-made output and the GDP level; and;

(v) causes productivity growth to decline in the traded sector, but the effect on productivity growth in the non-traded sector is ambiguous.

PROOF. See Appendix B.

Property $(i.a)$ means that there are two opposite effects on employment in the non-traded sector: The labor force declines as the woman uses more labor in the household sector, but a larger share of the remaining labor force is employed in the non-traded sector. As the latter effect dominates, the non-traded sector enlarges. The traded sector, on the other hand, contracts, and contracts even stronger than in traditional Dutch disease models due to the additional effect from the reduced female labor force participation.

Similar to the gender segregated economies, enhanced natural resource intensity increases the gab between production and consumption of the traded good, which in turn pushes the real exchange rate upwards. As women withdraw from the labor force, however, and as the share of the remaining labor force in the traded sector declines, production of the traded good declines as well. This feedback effect draws the real exchange rate downwards. Moreover, the change in $p_{1t}^{ML}(\xi)^*$ also depends on employment in the non-traded sector. As this employment goes up, to keep budget shares constant, $p_{1t}^{ML}(\xi)^*$ adjusts downwards. As a result, despite a contraction of the traded sector, the real exchange rate does not necessarily appreciate. For these reasons, also the man-made output level, as well as the GDP level, may increase or decline.

It is intuitive that the wage rate increases. As fewer labor resources are employed in the traded sector, marginal labor productivity increases. As the wage is identical across sectors in the *ML* economy, both men and women earn the same - higher - wage.

The change in natural resource intensity affects the growth rate through several channels. First, as women decrease their labor supply, less learning by doing is generated. Second, the expansion of non-traded sector has a direct positive effect on learning by doing in this sector and on the spillover to the traded sector. Third, however, as the traded sector contracts, there is less learning by doing in the traded sector, and less spillover of learning by doing to the non-traded sector.

When $\delta = 1$, the positive learning by doing effect from the non-traded sector onto growth is smaller than the negative learning by doing effect from the contracting traded sector. In this case,

$$\frac{\partial g_1^{ML}(\xi)^*}{\partial \xi} = \frac{\partial g_2^{ML}(\xi)^*}{\partial \xi} = \frac{\eta(\xi)^*}{\partial \xi} \left\{ \frac{-\frac{\mu}{\phi}\frac{\gamma}{\alpha}}{\left[\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^* + 1\right]^2} \right\} 2L < 0.$$

When spillovers are completely missing, i.e., when $\delta = 0$, then

$$\begin{aligned} \frac{\partial g_1^{ML}(\xi)^*}{\partial \xi} &= \frac{\eta(\xi)^*}{\partial \xi} \left[\frac{1}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^* + 1} \right]^2 2L > 0, \\ \frac{\partial g_2^{ML}(\xi)^*}{\partial \xi} &= \frac{\eta(\xi)^*}{\partial \xi} \left\{ \frac{-\frac{\mu}{\phi}\frac{\gamma}{\alpha} + 1}{\left[\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^* + 1\right]^2} \right\} 2L < 0. \end{aligned}$$

In this case, increased resource intensity has a positive effect on productivity growth in the non-traded sector, as it depends only this sector's employment.

When spillovers are not perfect, we notice furthermore that, like the *WiT* economy, productivity growth in the traded sector is damaged relatively more than productivity growth in the non-traded sector. Hence, if $\eta(\xi)^* > \frac{1}{2}$, i.e., if $g_1^{ML}(\xi)^* > g_2^{ML}(\xi)^*$, the extra resource revenue makes the real exchange rate depreciate at an even higher rate than prior to the change, whereas if $\eta(\xi)^* < \frac{1}{2}$, i.e., if $g_1^{ML}(\xi)^* > g_2^{ML}(\xi)^*$, the extra revenue makes the real exchange rate appreciate at slower rates.

5.4 Discussion

In terms of resource impact, the previous section demonstrates considerable variation in the Dutch disease symptoms among the three template economies. Our model illustrates, not only how labor market structures influence the resource impact, but also how, in turn, resource intensity influences women's labor force participation.

The *MiT* economy has a high level of gender equality in how the natural resource impacts the economy. High resource intensity does not effect women's labor supply, and, assuming men earn a higher wage that women, men's and women's wages become more equal at higher resource levels. In contrast, resources have an adverse effect on women's labor force participation in both a *WiT* and *ML* economy. Women at work in these two economies, become more isolated the higher the demand for the home good. One may argue that this isolation is likely to restrain these women's abilities to further their own interests, and, consequently, leave the male part of the labor force in power to rule society. This hypothesis is examined empirically in Ross (2006). He argues that women in the Middle East predominantly work export sectors based on manufacturing; thus the Middle East economies resemble the *WiT* economy, or a modified *ML* economy in which men can work in all sectors, but women can only work in trade. Ross finds that women in *oil rich* Middle East nations hold fewer seats in parliament and are less represented in the non-agricultural labor force than women in Middle East nations with *fewer oil* resources, which is precisely what our model predicts.

At the same time, our model may also explain why women in OECD-countries with a large share of GDP in natural resources, such as, e.g., Canada and New Zealand, despite the resources, comprise above 40 percent of total employment (Anker 1998). Women in these countries occupy a large portion of jobs in the non-traded sector, such as in sales and services, as depicted in table 2 above. Exactly this type of economy resembles our *MiT* economy in which female labor force participation rates are unaffected by resource revenues.

In addition, our model can be paralleled to the general literature on female labor force participation rates. Within this literature, a number of cross country studies have found a U-shaped relationship between female labor force participation rates and per capita GDP levels (Goldin 1995; Mammen and Paxson 2000). The downward sloping section of the U-shaped pattern is in conformity with our analysis of a WiT economy and ML economy, in which, the GDP level effect caused by increased resource intensity is positive. These scenarios predict exactly a negative relationship between female labor force participation and GDP levels. Women withdraw from the labor force because, in response to the higher income levels, the household good is demanded more.

6 Concluding Remarks

By studying labor mobility - and labor immobility - across formal sectors, and endogenous female labor supply, we explain manifold economic adjustment outcomes to increased resource intensity within a Dutch disease model. In particular, our analysis shows that labor market patterns are crucial to the adjustment outcome.

When sectors are *gender segregated*, whether women work in the traded or in the non-traded sector determines how the economy responds to increased resource intensity. In both economies, such a change results in higher demand for the household good as well as the non-traded good. If women work in the traded sector, they supply less labor to the formal sector to meet increased demand for the household good. In contrast, if women work in the non-traded sector, factor allocation and labor supply remains unchanged, since both goods in question are produced by women. Growth arises from learning by doing and depends on the size, and the allocation, of the labor force. Thus, growth is unaffected by increases in the resource inflow when women work in the non-traded sector and adversely affected when women work in the traded sector. Despite the latter adverse growth effect, higher resource intensity is, nevertheless, a blessing in terms of improving the GDP level.

When labor is *mobile between formal sectors*, i.e., when men and women work in the same sectors, as resource intensity increases, women withdraw from the labor force to meet demand for the household good. At the same time, a larger share of the remaining labor force is allocated to the non-traded sector to meet demand for the non-traded good. Due to this complexity of the labor-reallocation adjustment to changed resource intensity, the GDP level only rises when the contraction of the traded sector is not too large; otherwise it declines, just as the productivity growth in the non-traded sector increases only when sectoral spillovers are absent. When sectoral spillovers are perfect, however, productivity growth, which in this case is identical in the two sectors, declines.

Also the resource impact on the real exchange rate and the wage rates depends on the gender-grouping of the labor market. The wage rates generally differ between sectors when labor is immobile. Moreover, when men work in trade, only female wages are boosted by increased resource intensity, whereas when men work in the non-traded sector, both female and male wages increase. There is merely one wage rate when labor is mobile. This wage rate is higher, the greater the resource intensity.

Our results demonstrate that linking labor market patterns to natural resource intensity may also explain certain structures of society. In particular, when women have employment possibilities in the traded sector, abundant natural resources "tie women to the home."

Future work may involve policy and welfare analysis. For this purpose, theoretical work that involves intergenerational considerations seems useful. For instance, Matsen and Torvik (2005) analyze a Dutch disease model with mobile labor and exogenously given labor supply and find that some reduction in growth is optimal.

A Appendix

A.1 Static Equilibrium of the MiT Economy

Using $l_1^{MiT}(\alpha, \gamma, \phi, \mu)^*$ and $l_{2t}^* = L$, from (24), the equilibrium price of the non-traded good is

$$p_{1t}^{MiT}(H_{1t,}H_{2t};\xi)^* = \frac{H_{2t}}{H_{1t}} L^{\beta-\alpha} \left(\frac{\mu}{\phi} \frac{\gamma}{\alpha} + 1 \right)^{\alpha} \frac{\phi(1+\xi)}{1-\phi(1+\xi)}, \tag{49}$$

and, likewise, the equilibrium imputed price of the household good is derived from (25) as

$$p_{3t}^{MiT}(H_{2t};\xi)^* = H_{2t} L^{\beta-\gamma} \left(\frac{\frac{\mu}{\phi}\frac{\gamma}{\alpha} + 1}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}} \right)^{\gamma} \frac{\mu(1+\xi)}{1-\phi(1+\xi)}. \tag{50}$$

Both equilibrium prices are functions of labor allocation and the adjusted budget shares. The higher the labor share in production in a given sector, the lower the equilibrium price of the corresponding output due to decreasing marginal productivity of labor. Moreover, the larger ξ, the larger the adjusted budget share, which implies a higher equilibrium price.

Due to the segmented nature of the labor market, wage rates generally differ between sectors. As $w_{1t}^{MiT} \equiv w_t^f$, and by (18), (28), and (50), the female wage rate in equilibrium is

$$w_t^f(H_{2t};\xi)^* = H_{2t} L^{\beta-1} \left(\frac{\mu}{\phi} \frac{\gamma}{\alpha} + 1 \right) \frac{\phi(1+\xi)}{1-\phi(1+\xi)}. \tag{51}$$

The wage rate in the traded sector is paid to men, so $w_{2t}^{MiT} \equiv w_t^m$, and, in equilibrium, is given as

$$w_t^m(H_{2t})^* = H_{2t} \beta L^{\beta-1} \tag{52}$$

by (20) and (19). We notice that the female wage rate depends directly on the resource intensity, which is a result of the impact the resource has on the price of the non-traded good. The male wage rate, on the other hand, depends on the world market price on the traded good, which is unaffected by the inflow of natural resources.

Man-made output is the sum of output in the two formal sectors,

$$y_t^{MiT}(H_{2t};\xi)^* = H_{2t} L^{\beta} \frac{1}{1-\phi(1+\xi)}, \tag{53}$$

and by (23), GDP can be derived as

$$GDP_t^{MiT}(H_{2t};\xi)^* = H_{2t}L^{\beta}\frac{1+\xi}{1-\phi(1+\xi)}. \tag{54}$$

A.2 Static Equilibrium of the WiT Economy

Using $l_2^{WiT}(\beta,\gamma,\phi,\mu,\xi)^*$and $l_{1t}^* = L$, the equilibrium price of the non-traded good can be expressed from (24):

$$p_{1t}^{WiT}(H_{1t,}H_{2t};\xi)^* = \frac{H_{2t}}{H_{1t}}L^{\beta-\alpha}\left[\frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)}\frac{\gamma}{\beta}+1}\right]^{\beta}\frac{\phi(1+\xi)}{1-\phi(1+\xi)}, \tag{55}$$

and likewise, the imputed price of the household good in equilibrium is by (25):

$$p_{3t}^{WiT}(H_{2t};\xi)^* = H_{2t}L^{\beta-\gamma}\frac{\left[\frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)}\frac{\gamma}{\beta}+1}\right]^{\beta}}{\left[\frac{\frac{\mu(1+\xi)}{1-\phi(1+\xi)}\frac{\gamma}{\beta}}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)}\frac{\gamma}{\beta}+1}\right]^{\gamma}}\frac{\mu(1+\xi)}{1-\phi(1+\xi)}. \tag{56}$$

The wage rate in the non-traded sector is earned by men. By (18) and (55):

$$w_t^m(H_{2t};\xi)^* = H_{2t}\alpha L^{\beta-1}\left[\frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)}\frac{\gamma}{\beta}+1}\right]^{\beta}\frac{\phi(1+\xi)}{1-\phi(1+\xi)}. \tag{57}$$

The wage rate within the traded sector is earned by women, and from (19) and (31):

$$w_t^f(H_{2t};\xi)^* = H_{2t}\beta L^{\beta-1}\left[\frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)}\frac{\gamma}{\beta}+1}\right]^{\beta-1}. \tag{58}$$

Man-made output, $y_t^{WiT}(H_{2t};\xi)^*$, is given as

$$y_t^{WiT}(H_{2t};\xi)^* = H_{2t}L^{\beta}\left[\frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)}\frac{\gamma}{\beta}+1}\right]^{\beta}\frac{1}{1-\phi(1+\xi)}, \tag{59}$$

and, by (23),

$$GDP_t^{WiT}(H_{2t};\xi)^* = H_{2t}L^{\beta}\left[\frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)}\frac{\gamma}{\beta}+1}\right]^{\beta}\frac{1+\xi}{1-\phi(1+\xi)}. \tag{60}$$

A.3 Static Equilibrium of the ML Economy

Using $l_3^{ML}(\alpha, \gamma, \phi, \mu, \xi)^*$, the equilibrium price of the non-traded good is derived from (24):

$$p_{1t}^{ML}(H_{1t}, H_{2t}; \xi)^* = \frac{H_{2t}}{H_{1t}}[2L - l_3(\xi)^*]^{\beta-\alpha}\frac{[1-\eta(\xi)^*]^\beta}{[\eta(\xi)^*]^\alpha}\frac{\phi(1+\xi)}{1-\phi(1+\xi)}, \tag{61}$$

and the equilibrium imputed price of the household good from (25):

$$p_{3t}^{ML}(H_{2t}; \xi)^* = H_{2t}[2L - l_3(\xi)^*]^\beta \frac{[1-\eta(\xi)^*]^\beta}{[l_3(\xi)^*]^\gamma}\frac{\mu(1+\xi)}{1-\phi(1+\xi)}. \tag{62}$$

By (19), the wage rate is given as

$$w_t^{ML}(H_{2t}; \xi)^* = H_{2t}\beta\left\{[1-\eta(\xi)^*][2L - l_3(\xi)^*]\right\}^{\beta-1}. \tag{63}$$

Man-made output is given as

$$y_t^{ML}(H_{2t}; \xi)^* = \frac{1}{1-\phi(1+\xi)}H_{2t}[1-\eta(\xi)^*]^\beta[2L - l_3(\xi)^*]^\beta. \tag{64}$$

and the GDP level, by (23), is

$$GDP_t^{ML}(H_{2t}; \xi)^* = \frac{1+\xi}{1-\phi(1+\xi)}H_{2t}[1-\eta(\xi)^*]^\beta[2L - l_3(\xi)^*]^\beta. \tag{65}$$

B Appendix

B.1 Proof of Proposition 1

We prove each property (i)-(v) in turn by differentiation.

B.1.1 Proof of *(i)*

By (28),

$$\frac{\partial l_{1t}^{MiT*}}{\partial \xi} = 0. \quad \square$$

B.1.2 Proof of *(ii)*

From (49)

$$\frac{\partial p_{1t}^{MiT}(\xi)^*}{\partial \xi} = \frac{H_{2t}}{H_{1t}} L^{\beta-\alpha} \left(\frac{\mu}{\phi} \frac{\gamma}{\alpha} + 1 \right)^{\alpha} \frac{\phi}{[1 - \phi(1+\xi)]^2} > 0. \quad \square$$

B.1.3 Proof of *(iii)*

By (51)

$$\frac{\partial w_t^f(H_{2t};\xi)^*}{\partial \xi} = H_{2t} L^{\beta-1} \left(\frac{\mu}{\phi} \frac{\gamma}{\alpha} + 1 \right) \frac{\phi}{[1 - \phi(1+\xi)]^2} > 0,$$

and by and (52)

$$\frac{\partial w_t^m(H_{2t})^*}{\partial \xi} = 0.$$

Let the female to male wage ratio be given by $\rho_t(\xi)^* \equiv \frac{w_t^f(\xi)^*}{w_t^m(\xi)^*}$. Then, by (51) and (52),

$$\rho(\xi)^* = \frac{\alpha + \frac{\mu}{\phi}\gamma}{\beta} \frac{\phi(1+\xi)}{1 - \phi(1+\xi)},$$

and

$$\frac{\partial \rho(\xi)^*}{\partial \xi} = \frac{\alpha + \frac{\mu}{\phi}\gamma}{\beta} \frac{\phi}{[1 - \phi(1+\xi)]^2} > 0. \quad \square$$

B.1.4 Proof of *(iv)*

By (53),

$$\frac{\partial y_t^{MiT}(\xi)^*}{\partial \xi} = H_{2t} L^{\beta} \frac{\phi}{[1 - \phi(1+\xi)]^2} > 0,$$

and by (54),

$$\frac{\partial GDP_t^{MiT}(\xi)^*}{\partial \xi} = H_{2t}L^{\beta}\left\{\frac{1}{[1-\phi(1+\xi)]^2}\right\} > 0. \quad \square$$

B.1.5 Proof of (*v*)

From (37),

$$\frac{\partial g_1^{MiT*}}{\partial \xi} = 0,$$

and from and (38),

$$\frac{\partial g_2^{MiT*}}{\partial \xi} = 0.$$

This proves property (v) and completes the proof of proposition 1. $\square$

B.2 Proof of Proposition 2

We prove each property (i)-(v) in turn by differentiation.

B.2.1 Proof of (*i*)

By (31), $\frac{\partial l_2^{WiT}(\xi)^*}{\partial \xi} = l_2^{WiT}(\xi)^*\left[-\frac{\frac{\mu\gamma}{1-\phi(1+\xi)}}{\mu\gamma(1+\xi)+\beta[1-\phi(1+\xi)]}\right] < 0.$ $\square$

B.2.2 Proof of (*ii*)

From (55),

$$\frac{\partial p_{1t}^{WiT}(\xi)^*}{\partial \xi} = \frac{p_{1t}^{WiT}(\xi)^*}{1-\phi(1+\xi)}\left[\frac{\frac{\mu(1+\xi)}{1-\phi(1+\xi)}\frac{\gamma}{\beta}(1-\beta)+1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)}\frac{\gamma}{\beta}+1}\right] > 0. \quad \square$$

B.2.3 Proof of (*iii*)

By (57),

$$\frac{\partial w_t^m(H_{2t};\xi)^*}{\partial \xi} = \alpha H_{1t}L^{1-\alpha}\frac{\partial p_{1t}^{WiT}(\xi)^*}{\partial \xi} > 0.$$

and by and (58)

$$\frac{\partial w_t^f(H_{2t};\xi)^*}{\partial \xi} = H_{2t}(\beta-1)\left[l_2^{WiT}(\xi)^*\right]^{\beta-2}\frac{\partial l_2^{WiT}(\xi)^*}{\partial \xi} > 0.$$

Let the female to male wage rate ratio be given by $\rho_t(\xi)^* \equiv \frac{w_t^f(\xi)^*}{w_t^m(\xi)^*}$. Then, by (57) and (58),

$$\rho(\xi)^* = \frac{\mu\gamma + \beta\left[\frac{1}{1+\xi} - \phi\right]}{\phi\alpha}.$$

and,

$$\frac{\partial\rho(\xi)^*}{\partial\xi} = \frac{-\beta}{\phi\alpha\left[1+\xi\right]^2} < 0. \ \square$$

B.2.4 Proof of (*iv*)

By (59),

$$\frac{\partial y_t^{WiT}(\xi)^*}{\partial\xi} = \frac{H_{2t}\left[l_2^{WiT}(\xi)^*\right]^\beta}{\left[1-\phi(1+\xi)\right]^2}\left[\phi - \frac{\mu\gamma\beta}{\mu(1+\xi)\gamma + \beta\left[1-\phi(1+\xi)\right]}\right] > 0$$

and by (60),

$$\frac{\partial GDP_t^{WiT}(\xi)^*}{\partial\xi} = \frac{H_{2t}\left[l_2^{WiT}(\xi)^*\right]^\beta}{\left[1-\phi(1+\xi)\right]^2}(1+\xi)\left[\frac{1}{1+\xi} - \frac{\mu\gamma\beta}{\mu(1+\xi)\gamma + \beta\left[1-\phi(1+\xi)\right]}\right] > 0. \ \square$$

B.2.5 Proof of (*v*)

From (39),

$$\frac{\partial g_1^{WiT}(\xi)^*}{\partial\xi} = \delta\frac{\partial l_2^{WiT}(\xi)^*}{\partial\xi} < 0$$

and, from (40),

$$\frac{\partial g_2^{WiT}(\xi)^*}{\partial\xi} = \frac{\partial l_2^{WiT}(\xi)^*}{\partial\xi} < 0.$$

This proves property (v) and completes the proof of proposition 2. $\square$

B.3 Proof of Proposition 3

We prove each property $(i.a)$-(v) in turn by differentiation.

B.3.1 Proof of (*i.a*)

By (33),

$$\frac{\eta(\xi)^*}{\partial\xi} = \left[\eta(\xi)^*\right]^2\frac{\beta}{\alpha}\frac{1}{\phi(1+\xi)^2} > 0,$$

and, by (34),

$$\frac{l_3^{ML}(\xi)^*}{\partial\xi} = \frac{\eta(\xi)^*}{\partial\xi}\frac{\frac{\mu}{\phi}\frac{\gamma}{\alpha}}{\left[\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^*+1\right]^2}2L > 0. \quad \square$$

B.3.2 Proof of (*i.b*)

As $l_1^{ML}(\xi,\cdot)^* = \eta(\xi)^*[2L - l_3^{ML}(\xi)^*]$, it follows that

$$\frac{l_1^{ML}(\xi)^*}{\partial\xi} = \frac{\eta(\xi)^*}{\partial\xi}\left[\frac{1}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^*+1}\right]^2 2L > 0. \quad \square$$

B.3.3 Proof of (*ii*)

From (61),

$$\frac{\partial p_{1t}^{ML}(\xi)^*}{\partial\xi} = p_{1t}^{ML}(\xi)^*\left\{\frac{1}{[1-\phi(1+\xi)](1+\xi)} - \frac{\frac{\eta(\xi)^*}{\partial\xi}}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^*+1}\left[\frac{\beta\left[\frac{\mu}{\phi}\frac{\gamma}{\alpha}+1\right]}{1-\eta(\xi)^*} + \frac{\alpha}{\eta(\xi)^*}\right]\right\}.$$

Thus,

$$\frac{\partial p_{1t}^{ML}(\xi)^*}{\partial\xi} > 0 \text{ if } \frac{1}{[1-\phi(1+\xi)](1+\xi)} > \frac{\frac{\eta(\xi)^*}{\partial\xi}}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^*+1}\left[\frac{\beta\left[\frac{\mu}{\phi}\frac{\gamma}{\alpha}+1\right]}{1-\eta(\xi)^*} + \frac{\alpha}{\eta(\xi)^*}\right],$$

otherwise

$$\frac{\partial p_{1t}^{ML}(\xi)^*}{\partial\xi} < 0. \quad \square$$

B.3.4 Proof of (*iii*)

By (63),

$$\frac{\partial w_t^{ML}(\xi)^*}{\partial\xi} = \beta H_{2t}(\beta-1)[l_2^{ML}(\xi)^*]^{\beta-2}\left[\frac{l_2^{ML}(\xi)^*}{\partial\xi}\right] > 0.$$

Since

$$\frac{l_2^{ML}(\xi)^*}{\partial\xi} = -\frac{\eta(\xi)^*}{\partial\xi}\frac{\frac{\mu}{\phi}\frac{\gamma}{\alpha}+1}{\left[\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^*+1\right]^2}2L < 0. \quad \square$$

B.3.5 Proof of (iv)

By (64)

$$\frac{\partial y_t^{ML}(H_{2t};\xi)^*}{\partial \xi} = y_t^{ML}(H_{2t};\xi)^* \left\{ \frac{\phi}{1-\phi(1+\xi)} + \beta \frac{\frac{l_2^{ML}(\xi)^*}{\partial \xi}}{l_2^{ML}(\xi)^*} \right\},$$

where

$$\frac{\frac{l_2^{ML}(\xi)^*}{\partial \xi}}{l_2^{ML}(\xi)^*} = -\frac{\frac{\eta(\xi)^*}{\partial \xi}}{[1-\eta(\xi)^*]} \frac{\frac{\mu}{\phi}\frac{\gamma}{\alpha}+1}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^*+1}$$

Hence,

$$\frac{\partial y_t^{ML}(H_{2t};\xi)^*}{\partial \xi} > 0 \text{ if } \frac{\phi}{1-\phi(1+\xi)} > \beta \frac{\frac{l_2^{ML}(\xi)^*}{\partial \xi}}{l_2^{ML}(\xi)^*},$$

otherwise,

$$\frac{\partial y_t^{ML}(H_{2t};\xi)^*}{\partial \xi} < 0.$$

From, (65)

$$\frac{\partial GDP_t^{ML}(\xi)^*}{\partial \xi} = y_t^{ML}(\xi)^* + (1+\xi)\frac{\partial y_t^{ML}(H_{2t};\xi)^*}{\partial \xi}.$$

Hence,

$$\frac{\partial GDP_t^{ML}(\xi)^*}{\partial \xi} > 0 \text{ if } \frac{1}{1+\xi} + \frac{\phi}{1-\phi(1+\xi)} > \beta \frac{\frac{l_2^{ML}(\xi)^*}{\partial \xi}}{l_2^{ML}(\xi)^*},$$

otherwise,

$$\frac{\partial GDP_t^{ML}(\xi)^*}{\partial \xi} < 0. \quad \square$$

B.3.6 Proof of (v)

By (41),

$$\frac{\partial g_1^{ML}(\xi)^*}{\partial \xi} = \frac{1}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^*+1} \frac{\eta(\xi)^*}{\partial \xi} \left\{ -\frac{\frac{\mu}{\phi}\frac{\gamma}{\alpha}[\eta(\xi)^* + \delta(1-\eta(\xi)^*)]}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^*+1} + 1 - \delta \right\} 2L.$$

Thus,

$$\frac{\partial g_1^{ML}(\xi)^*}{\partial \xi} \geq 0 \text{ if } 1 \geq \delta + \frac{\frac{\mu}{\phi}\frac{\gamma}{\alpha}[\eta(\xi)^* + \delta(1-\eta(\xi)^*)]}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^*+1}$$

otherwise,

$$\frac{\partial g_1^{ML}(\xi)^*}{\partial \xi} < 0.$$

By (42),

$$\frac{\partial g_2^{ML}(\xi)^*}{\partial \xi} = \frac{1}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^* + 1}\frac{\eta(\xi)^*}{\partial \xi}\left\{-\frac{\frac{\mu}{\phi}\frac{\gamma}{\alpha}}{\frac{\mu}{\phi}\frac{\gamma}{\alpha}\eta(\xi)^* + 1}[1 + \eta(\xi)^*(\delta - 1)] + \delta - 1\right\}2L < 0.$$

This proves property (v) and completes the proof of proposition 3. □

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