On the determinants of structural change: an exploratory model

Francisco Adilson Gabardo[a], Gabriel Porcile[b], João Basilio Pereima[c]

[a]*Researcher at Nucleo of Economics and Complexity (NeX), Federal University of Paraná (UFPR)*
[b]*Economic Commission for Latin America and the Caribbean (ECLAC), Chile and Department of Economics, Federal University of Paraná (UFPR)*
[c]*Associate Professor of Economics at Federal University of Paraná (UFPR)*

Abstract

Economists still struggle to understand why some countries are so much richer than others. The shift of labour out of the agricultural sector into other such sectors as manufacturing and services is one important piece of this puzzle. Therefore, understanding not only the driving mechanisms and forces behind the process of structural change but also how these mechanisms interact and reinforce each other is crucial. In the present work we develop a parsimonious computational agent-based model (ABM) where structural change is driven by income and relative-price effects simultaneously. The income effect is generate by the assumption of a simple non-homothetic hierarchical demand structure where consumers spend their income according to a given priority as in Falkinger (1990, 1994) and Andersen (2001). The relative price effect derives from different rates of sectoral productivity growth. Our objective is not to present a full picture of the process of structural change, but to demonstrate that, given certain assumptions regarding agents' behaviour, the two effects proposed by the literature (income and relative-price) are not competing but actually complementary and mutually necessary to replicate the macroeconomic patterns observed in reality.

Resumo

Economistas ainda lutam para entender por que alguns países são muito mais ricos do que outros. A migração da mão-de-obra da agricultura para a manufatura e para os serviços é uma peça fundamental desse quebra-cabeça. Portanto, compreender não apenas os mecanismos e forças que impulsionam o processo de mudança estrutural, mas também como esses mecanismos interagem e se retroalimentam é crucial. No presente trabalho, desenvolvemos um modelo computacional baseado em agentes onde a mudança estrutural origina-se de efeitos renda e preço-relativo simultaneamente. O efeito renda é gerado a partir de uma estrutura de demanda não-homotética e hierárquica onde os consumidores gastam suas rendas de acordo com uma determinada prioridade como em Falkinger (1990, 1994) e Andersen (2001). O efeito preço-relativo resulta de diferentes taxas de crescimento da produtividade setorial. Nosso objetivo não é apresentar um quadro completo do processo de mudança estrutural, mas sim demostrar que, dados certos pressupostos com relação ao comportamento dos agentes, os dois efeitos propostos pela literatura (renda e preço-relativo) não são concorrentes, mas sim complementares e mutuamente necessários para reproduzir os padrões macroeconômicos observados na realidade.

Keywords: Growth, Structural Change, Income Effect, Relative-Price Effect, Agent-based Model
JEL: O00;O41;L16

Área 2: Desenvolvimento Econômico

Email addresses: `franciscogabardo@ufpr.br` (Francisco Adilson Gabardo), `porcile@ufpr.br` (Gabriel Porcile), `joaobasilio@ufpr.br` (João Basilio Pereima)

1. Introduction

Economists have struggled for centuries to understand why some countries are so much richer than others. This might be the single most complex question in all of economic theory. This question is particularly challenging as the factors that make a country rich may vary not only across countries but also within countries across time. Factors and conditions that once benefited a particular nation's development might not be present or be effective at a different time or might not have the same effect on a different nation.

Despite all the progress done in the understanding of the mechanisms behind the process of economic growth, there are still many unanswered questions. However, over the years, economists have identified some pervasive features of the process of economic growth and development. Among these features, is the shift of labour out of the agricultural sector into other such sectors as manufacturing and services.

Economists know that the large heterogeneity that we see today in countries' income levels is the result of a combination of endogenous and exogenous factors. However, when we look at the data we are able to identify some common features among poor countries. Caselli (2005) observes that there are three proximate reasons for poor countries' poverty: their much lower labour productivity in agriculture; their somewhat lower labour productivity outside agriculture; and their larger share of employment in the sector that – on average – is less productive. This empirical observation can be seen evidence that economic growth and structural change are close companions.

Structural change can be defined as the reallocation of labour and other resources across the agriculture, manufacturing, and service sectors. A broader definition, however, would also encompass the changes in the structure of production and employment within and between all sectors[1] of the economy as well as the emergence of new sectors and the disappearance of old ones (Gabardo et al., 2017). As part of this larger and longer process of structural change, the decline of the agricultural sector has led to a massive transformation of the economic landscape in today's developed and rich nations. The process of industrialization has not only dramatically changed the size and share of sectors in those economies, but also the size of their cities and ultimately their people's way of life (Gabardo et al., 2017).

There are basically two reasons that make economists believe that this pattern of labour reallocation out of agriculture is a necessary condition of the process of growth. First, per capita demand for agricultural goods is relatively price- and income-inelastic at high levels of income. Second, the presence of a dominant fixed factor in agricultural production (land) limits the ability of the agricultural sector to absorb labour in the face of growing population levels (Foster and Rosenzweig, 2007). Therefore, understanding the causes not only of this labour reallocation out of agriculture but out of the manufacturing and into the service sector is of great importance.

Despite its prominence and substantial empirical macroeconomic literature, in a theoretical perspective the study of structural change has been given less attention than that of economic growth. Only in the last two decades that the subject of structural change has gained more prominence and has become a relevant research area[2]. The existing literature has advanced several explanations to account for the process of structural change. However, there are three channels or explanations that have received more attention and have been better developed (Dennis and İşcan, 2009, p.187):

1. A version of Engel's Law operating on employment shares: as incomes rise, agriculture sheds labour due to the low income elasticity of demand for farm goods;

---

[1]In the literature, a sector is often equivalent to an industry. Thus, it is possible to say that the manufacturing sector is composed of several manufacturing industries. As in Herrendorf et al. (2014), we use the term manufacturing to refer to activities neither classified as agriculture nor as service.

[2]Krüger (2008), Matsuyama (2008), Silva and Teixeira (2008) and Gabardo et al. (2017) review the literature on structural structural change.

2. A version of Baumol's (1967) "cost disease": relatively faster productivity growth in agriculture pushes farm workers to produce complementary non-farm goods;

3. Different factor intensities in production: agricultural production is more conducive to rapid capital deepening, which in turn pulls labour into the more labour intensive non-farm sector.

These three explanations or channels seek to account for the process of structural change by means of different mechanisms. The first explanation is a demand side based explanation, while the second and third are supply side ones. The first channel, also called the income or utility-based explanation, relies on differences in income elasticities of demand across sectors. This explanation goes back to Fisher (1935) and Clark (1940), who applied Engel's law to the demand for manufacturing goods. Proponents of this explanation, have suggested that if one assumes non-unitary expenditure elasticities of demand (non-homothetic preferences), then changes in income lead to changes in expenditure shares and to labour reallocation across sectors even if relative prices are constant. The utility-based explanation is consistent with Engel's law[3], which is not only valid for basic or necessity goods but is a more general law of consumption[4]. Many authors rely on this channel to explain the process of structural change, including Matsuyama (1992), Echevarria (1997), Laitner (2000), Kongsamut et al. (2001), Gollin et al. (2002) and Foellmi and Zweimüeller (2008).

The second and third channels rely on changes in relative prices. These changes affect sectoral expenditure and labour shares whenever the elasticity of substitution across sectors is different from one. In the second channel, relative prices change as a result of differential productivity growth across sectors. This explanation goes back to Baumol (1967) and was recently formalized by Ngai and Pissarides (2007), which assert that structural change results from differences in the (exogenous) rates of total factor productivity across sectors. These differences cause changes in relative prices which induce the reallocation of labour across sectors.

In the third channel, relative prices change as a result of changes in the relative prices and supply of inputs if sectors factor's intensities in production are different. In this case, one can generate structural transformation via relative price changes even if technological change is neutral (Herrendorf et al., 2014). This last mechanism is described in the literature in two papers Caselli and Coleman (2001) and Acemoglu and Guerrieri (2008). In Caselli and Coleman (2001), skilled and unskilled workers are the two inputs of interest, while in Acemoglu and Guerrieri (2008) the two inputs are capital and labour. The former argue that as a result of a decrease in the cost of education in the first half of the 20th century, there was an increase in the relative supply of skilled workers which decreased the relative price of non-agricultural goods, and moved resources out of agriculture. The later allows for differences in sectoral capital intensities, which as growth driven by technological change is associated with an increase in the capital-to-labour ratio, lead to differential capital deepening across sectors.

Most authors see the income and the relative price effects as competing explanations. However, there is no evidence in the literature that proofs that they cannot simultaneously determine and drive the process of structural change. Furthermore, Boppart (2014) provides empirical evidence that both drivers of structural change are relevant. Since both explanations describe the same phenomenon, their integration, despite being a natural step, is a theoretical challenge. By combining non-homothetic

---

[3]In his famous 1857 article, Ernest Engel produced empirical evidence showing that the poorer a family is, the larger the budget share it spends on nourishment. This empirical regularity is known as Engel's law. Ernest Engel's analysis initially suggested that as income rises, the proportion of income spent on food falls, even if actual expenditure on food rises. Moreover, he argued that such a change in the composition of demand implies that, as the economy grows and per capita income increases, new resources can be dedicated to the production of other goods unrelated to food (Engel, 1857, p. 50). The relation that describe how expenditure on a particular good or service depends on income is called Engel curve.

[4]Deaton and Muellbauer (1980) concluded that the vast majority of studies obtains the result that the expenditure share of a product changes systematically with income.

preferences and differential TFP growth, Boppart (2014) developed one explanation of how the process of structural change can be driven by income and the relative price effects simultaneously.

Notwithstanding the recent contributions, the microeconomic foundations of the transition from an agriculture-based economy to a diversified industrial and to a services-based economy are still poorly understood. The process of structural change is a complex phenomenon. Its understanding demands not only the analysis of the microeconomic behaviour of firms and consumers but also the analysis of the interaction between demand and supply forces that generate sectoral reallocation of resources. In a comprehensive review of the subject, Krüger (2008) observes that in all the theories that he reviewed, technological progress drives structural change, but it is frequently the demand side that is crucial for determining which industries grow faster than others and which shrink, and it therefore shapes the direction of structural change. Moreover, Krüger (2008) continues and points out that further research, particularly on the feedback effects between structural change and aggregate growth, should therefore deserve much more attention. He suggests that the theoretical explanation of these issues almost surely requires other means of analysis than used so far and concludes arguing that agent-based computational models analysed by simulation methods might be an alternative (Krüger, 2008, p.357).

Agent based models that integrate growth and structural change are fairly recent in the literature, some examples are Lorentz and Savona (2008); Ciarli et al. (2010); Ciarli and Lorentz (2010); Ciarli (2012); Lorentz et al. (2016); Ciarli and Valente (2016). This methodology help us to understand how individual decisions give rise to patterns, how these patterns in turn affect individual behaviour, and the dynamics that emerge from this interaction at the macro level. Agent-based models allow for a dynamical more realistic and evolutionary representation of the economic system (Gräbner, 2016), therefore being suitable to exploring the dynamics of growth and structural change.

In the present article we develop a parsimonious agent-based model where structural change is driven by income and the relative price effects simultaneously. The income effect is generate by the assumption of a simple non-homothetic hierarchical demand where consumers spend their income according to given priorities as in Falkinger (1990, 1994)and Andersen (2001). The relative price effect results from different rates of sectoral productivity growth. The model developed here is not aimed at presenting a full picture of the process of structural change. We seek to contribute to the literature by theoretically showing the possibility that the two proposed explanations of structural change are not competing but actually complementary and mutually necessary to replicate the macroeconomic patterns observed in reality.

The remaining of the article is organized as follows: the next section briefly presents some of the empirical regularities and stylized facts about the process of structural change. Sections 3 and 4 present the model and the simulation results respectively. Section 5 presents our concluding remarks.

2. Some empirical regularities and stylized facts about structural change

In his Nobel lecture, Simon Kuznets summarized six characteristics of modern economic growth that emerged from his analysis based on conventional measures of national product and its components: population, labour force, and the like. The third of his six characteristics states that "the rate of structural transformation of the economy is high. Major aspects of structural change include the shift away from agriculture to nonagricultural pursuits and, recently, away from industry to services."(Kuznets, 1973, p.248).

Simon Kuznets was among the first economists to empirically describe the process of structural change. Some of the early empirical studies are Fischer (1939), Clark (1940), Kuznets (1957), Chenery (1960). Since then, much effort has been done by many researchers to reconstruct historical data in order to provide a more comprehensive picture of this process. Important contributions were made by Maddison (1987), Syrquin (1988), Kaelble (1997), Dennis and İşcan (2009), Buera and Kaboski

(2012), Broadberry et al. (2013) and Herrendorf et al. (2014) and many others[5]. Some authors like, Gollin et al. (2002) and Alvarez-Cuadrado and Poschke (2011) focused on the role of agriculture productivity in the process of industrialization and on the fall in the share of agriculture in output and employment that accompanied long-run increases in income per capita.

To give an example of the magnitude of transformation that occurred in the last centuries, Maddison (1987) described the reallocation of labour in six major industrialized countries (France, Germany, Japan, Netherlands, U.K. and U.S.) showing that the average employment share in agriculture was 46.0% in 1870 and fell to 5.5% by 1984. During the same period, the average employment share in the service sector increased from 26.4% to 62.2%. The most commonly observed pattern of structural change is characterized by a systematic fall in the share of labour allocated to agriculture over time, by a steady increase in the share of labour in services, and by a hump-shaped pattern for the share of labour in manufacturing (Gabardo et al., 2017).

Herrendorf et al. (2014) published one of the most comprehensive studies in recent years on structural change. Many of the stylized facts observed earlier were confirmed and a broader picture unfolded as we can see in figure (1). There are other important empirical observations that worth mention. Gollin et al. (2002) reported a negative relationship between agricultural productivity and the share of employment in agriculture. This same relationship holds for the productivity of agriculture relative to non-agriculture. The same authors conclude that growth in agricultural productivity is quantitatively important in understanding the growth of GDP per worker for developing countries. On average, the contribution of agricultural growth, non-agricultural growth, and sectoral shifts are 54%, 17%, and 29%, respectively (Gollin et al., 2002).

The agent-based model developed in the next section theoretically replicates the above presented empirical regularities. The objective of this exercise is to demonstrate that, in order to replicate the kind of structural change pattern observed in the data, the two effects described in the literature as the sources of the process of structural change, namely the income and the relative price effect, must coexist.

3. The Agent-based model

We build a general *disequilibrium* agent-based model where agents are boundedly rational and follow simple rules of behaviour in an incomplete and asymmetric information context. The model depicts a three-sector economy (agriculture, manufacturing and services) where each sector is populated by heterogeneous firms that follow the same strategies regarding pricing, investment on R&D and sales expectation formation. Nevertheless, since success in innovating is a stochastic process, their productivities and unit costs are different and consequently, they have different cash-flows, profit and price levels, demand and financing needs. The resulting differential growth rates of firms' productivities generates a relative price effect. Moreover, the availability of labour is not the same for all firms, as we assumed a generic labour market where all firms in all sector pay the same salary the rule of "first come, first served" determines which firms get the available labour hours.

In the present model, firms not only produce goods and invest in R&D but also interact with a generic banking system by taking out loans to finance their negative cash flow (negative profit). If a firm has negative profit it will have to finance it by taking out a loan on the amount of the negative profit. Financing allows firms to continue operating even with losses. In the current version of the model firms do not go bankrupt and the lending interest rate is fixed throughout the simulation. The bank system only finance firms.

On the demand side, in each period, consumers observe the prices charged by a random subset of (χ)[6] firms and consume following to a hierarchical rule, spending their income according to given

---

[5]The list of contributions is too large for it to be included in its entirety.

[6]This parameter reflects the degree of imperfect information on the consumers side
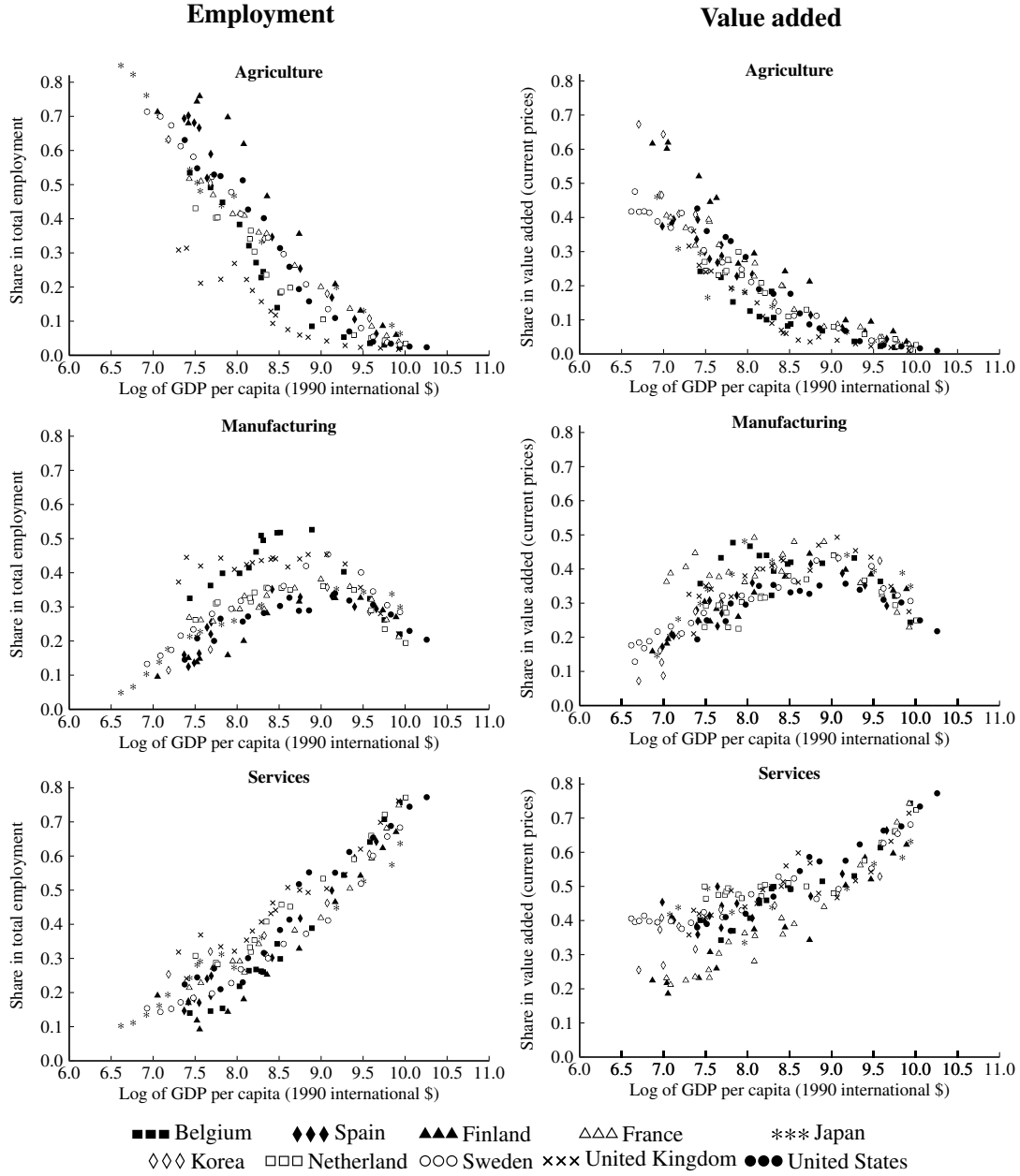
Figure 1: Sectoral Shares of Employment and Value Added - Selected Developed Countries 1800-2000, computed by Herrendorf et al. (2014)

priorities and to the availability of the goods in the subset of firms observed. The rule establishes that any consumer wants to consume a satisfactory (satiation) level of one good before consuming anything of the next good in the hierarchy. If the consumers is not able to buy the quantity desired and the disposable income is not spent on its entirety, the consumer saves and uses the money to consume in the next period. Thus saving is not a conscious decision of the consumer. This simple non-homothetic hierarchical demand structure generates an income effect in the economy.

In the following subsections we firstly describe the sequence of events that takes place at each time step. Subsequently, we explain the firms and consumers' behaviour in greater detail.

3.1. Sequence of events

In each period of the simulation, the following sequence of events takes place:

1. *Firms' expected demand*: firms compute their expected demand ($s^e_{z,i,t}$) based on past sales ($s_{z,i,t-1}$), unfulfilled orders ($us_{z,i,t}$) and expected demand ($s^e_{z,i,t-1}$).

2. *Production planning*: firms confront their level of inventories $(inv_{z,i,t-1})$[7] and their current production capacity, given by their level of productivity $(a_{z,i,t-1})$ and their workforce $(l_{z,i,t-1})$, with their expected demand.

3. *Firms' labour demand*: firms decide to increase, decrease or to keep unchanged their workforce whether $(s^e_{z,i,t} > inv_{z,i,t-1} + a_{z,i,t-1}l_{z,i,t-1})$, $(s^e_{z,i,t} < inv_{z,i,t-1} + a_{z,i,t-1}l_{z,i,t-1})$ or $(s^e_{z,i,t} = inv_{z,i,t-1} + a_{z,i,t-1}l_{z,i,t-1})$ respectively.

4. *Production*: Firms produce consumption goods and put in the goods market their current period production $(x_{z,i,t})$ and previous period inventories $(inv_{z,i,t-1})$.

5. *Wages and R&D expenses.*: Firms pay their workers. Firm's wage bill is given by $(wb_{z,i,t} = l_{z,i,t}w_t)$. Moreover, firms pay workers for R&D expenses.

6. *Desired consumption*: Individuals decide their satisfactory (satiation) consumption level for each good based on the growth of their income, which is composed of wages, R&D income and dividends.

7. *Effective consumption*: Individuals randomly select (χ) firms from each of the three sectors, compare their prices, their disposable income (income + savings) and their desired consumption level and calculate how many units of each good they are willing and able to purchase.

8. *Consumption*: Individuals and firms interact in the goods market. As a result, some individuals totally satisfy their desired consumption level for one or all goods, while others may remain with residual cash; on the other hand, some firms sell all the produced output, while others may accumulate inventories.

9. *Savings*: Individuals with residual cash after consumption deposit their cash in the banking system and receive interest (i^d) on it.

10. *Profits*: Firms calculate gross and net profits, if indebted they repay their debt in full or in part or if they have negative profits they take out new loans.

11. *Dividends and Accumulated Profits*: If firms generate positive net profits they distribute a share δ as dividends and keep the rest as accumulated profits.

12. *Aggregate Variables*: Sector and Economy level variables are computed and the cycle restarts.

In the next sections we explain the firms and consumers' behaviour in greater detail.

3.2. Expected sales and production

In the model, firms' production is jointly determined by demand and supply elements. Since we are interested in describing the labour dynamics under structural change, we assume a pure labour economy. Production oscillations are determined by variations on the quantity of labour employed at each period, by the technology available and by the level of inventories. As the present version of the model is intended to be very parsimonious, technical change, when it happens, takes the form of process rather than product innovation, so that "growth" means producing more of the same good(s).

Although the absence of physical capital may at first seem strange, one needs to beware that most "growth" models that give rise to sustained growth are either based on endogenously determined accumulation of knowledge or exogenously given technological change. Frequently, models built

---

[7]We assume that only firms in the agriculture and in the manufacturing sectors do accumulate inventories, firms in the service sector cannot accumulate inventories

around the accumulation of physical capital are not capable of generating sustained growth. The present model focuses on the endogenous accumulation of knowledge to generate increases in income-per-capita and dispenses physical capital altogether. The process through which firms increase their productivities will be described later on subsection 3.5.

The economy is divided into three consumption sectors ($z = 1, 2, 3$) namely: agriculture, manufacturing and services. Each sector produces a different final good which satisfy one consumer need. Sectors are composed of N^F firms. For simplicity, the economy has a fixed labour supply. Firms start the cycle by computing their expected sales ($s_{z,i,t}^e$) through a simple adaptive scheme based on past sales ($s_{z,i,t-1}$), unfulfilled orders ($us_{z,i,t}$) and expected sales ($s_{z,i,t-1}^e$):

$$s_{z,i,t}^e = s_{z,i,t-1}^e + \lambda_s[(s_{z,i,t-1} + us_{z,i,t-1}) - s_{z,i,t-1}^e] \tag{1}$$

Once firms have determined the amount of goods they want to produce based on their expected sales they turn to their production capacity and to their inventories. Only firms in the agriculture and in the manufacturing sectors do accumulate inventories. Inventories in these firms are computed according to:

$$inv_{z,i,t} = (x_{z,i,t} + inv_{z,i,t-1}) - s_{z,i,t} \tag{2}$$

Given their inventories and their expected sales, firms define how many units they would have to produce, that is $s_{z,i,t}^e - inv_{z,i,t-1}$. At this point, after assessing their current productivity ($a_{z,i,t-1}$) and labour force ($a_{z,i,t-1}$), firms decide to increase, decrease or to keep unchanged their workforce whether ($s_{z,i,t}^e > inv_{z,i,t-1} + a_{z,i,t-1}l_{z,i,t-1}$), ($s_{z,i,t}^e < inv_{z,i,t-1} + a_{z,i,t-1}l_{z,i,t-1}$) or ($s_{z,i,t}^e = inv_{z,i,t-1} + a_{z,i,t-1}l_{z,i,t-1}$) respectively. In the case that firms decide to reduce their labour force, they will fire workers, that means, reduce l up to the point where ($s_{z,i,t}^e = inv_{z,i,t-1} + a_{z,i,t-1}l_{z,i,t}$). In the second case, if a firm decides to increase its labour force, it will have to go to the labour market and check if there are any labour hours available. If there are no labour hours available, the firm sticks to $l_{z,i,t-1}$ and produces less than what it wanted. However, if there are labour hours available, the firm will try to hire then. Here there is a coefficient that determines how many hours of work the firm is able to hire when there are labour hours available. This is the labour hiring rigidity coefficient ($\gamma_L \in (0; 1]$). What this coefficient does is it limits the firm's ability to hire all the workers that otherwise it would like to. Let us imagine that a firm wants to hire a quantity $l_{z,i,t} - l_{z,i,t-1}$, if there are labour hours available in the market, the firm will be able to hire $\gamma_L(l_{z,i,t} - l_{z,i,t-1})$ hours. If the amount of labour hours available is less than $\gamma_L(l_{z,i,t} - l_{z,i,t-1})$, the firm hires all that is available. Since the wage rate is uniform across all sectors and firms and there is no matching protocol of any kind, the allocation of labour hours to firms is based on a simple "first come, first served" rule.

After adjusting their labour force, firms finally carry out production. Actual production can be represented by the following expression:

$$x_{z,i,t} = min(s_{z,i,t}^e - inv_{z,i,t-1}, x_{z,i,t}^{max}) \tag{3}$$

where $x_{z,i,t}^{max}$ is the maximum production capacity determined by the level of productivity and the firm's labour force according to:

$$x_{z,i,t}^{max} = a_{z,i,t-1}l_{z,i,t} \tag{4}$$

The reader must have noticed that, by the design of the equations, it is possible that ($s_{z,i,t}^e - inv_{z,i,t-1} > x_{z,i,t}^{max}$), but it is not possible to have ($s_{z,i,t}^e - inv_{z,i,t-1} < x_{z,i,t}^{max}$). This means that, although firms can accumulate inventories (except service sector) they cannot have excess capacity. At every time step, each firm's supply of goods is:

$$xs_{z,i,t} = x_{z,i,t} + inv_{z,i,t-1} \tag{5}$$

3.3. Price, mark-up, income and firms' profit

Once firms have finished producing their goods they are able to calculate their unit costs and selling prices. Firms unit costs $uc_{z,i,t}$ are calculated in a straightforward manner:

$$uc_{z,i,t} = \frac{wb_{z,i,t}}{x_{z,i,t}} \tag{6}$$

where $(wb_{z,i,t})$ is given by:

$$wb_{z,i,t} = (\nu_z w_t) l_{z,i,t} \tag{7}$$

the wage rate (w_t) is determined at the economy level and its calculation is explained on subsection 3.7. The parameter (ν_z) is used to adjust the aggregated wage rate so that sectors may have different wage rates.

Before firms are able to set their prices they have to determine their mark-up[8]. Firms' mark-ups are variable and dependent on the difference between their past expected sales $(s^e_{z,i,t-1})$, sales $(s_{z,i,t-1})$ and unfulfilled orders $(us_{z,i,t-1})$. A firm's mark-up is given by:

$$\mu_{z,i,t} = \mu_{z,i,t-1} + \sigma^\mu[(s_{z,i,t-1} + us_{z,i,t-1}) - s^e_{z,i,t-1}] \tag{8}$$

where (σ^μ) is the mark-up adjustment coefficient. After having calculated their unit costs and mark-up rates, firms set their prices according to:

$$p_{z,i,t} = uc_{z,i,t}\mu_{z,i,t} \tag{9}$$

After firms and individuals have interacted in the goods market, firms assess their sales, inventories, unfulfilled orders, R&D and financial expenses and calculate their operational, gross and net profits. Firms operational profits are given by:

$$\pi^o_{z,i,t} = s_{z,i,t}p_{z,i,t-1} - wb_{z,i,t} - (inv_{z,i,t-1}uc_{z,i,t-1} - inv_{z,i,t}uc_{z,i,t}) \tag{10}$$

Firms gross profits are given by:

$$\pi^g_{z,i,t} = \pi^o_{z,i,t} - fin^{exp}_{z,i,t} + fin^{rev}_{z,i,t} - rd_{z,i,t} \tag{11}$$

where $(fin^{exp}_{z,i,t})$ and $(fin^{rev}_{z,i,t})$ are the firms financial expenses and revenues. These variables are explained on subsection 3.4. The variable $(rd_{z,i,t})$ is the firms expenses with R&D. This variable's calculation and importance are discussed on subsection 3.5.
Firms' net profits are given by:

$$\pi^n_{z,i,t} = \begin{cases} \pi^g_{z,i,t} - debt_{z,i,t-1}, & \text{if} \quad \pi^g_{z,i,t} > debt_{z,i,t-1} & (12) \\ 0, & \text{if} \quad \pi^g_{z,i,t} < debt_{z,i,t-1} & (13) \end{cases}$$

After having calculated their net profits, if they are positive firms will distribute all or part of them as dividends and keep the rest as accumulated profits. Thus, firms dividends are calculated according to:

$$div_{z,i,t} = \begin{cases} \delta\pi^n_{z,i,t}, & \text{if} \quad \pi^n_{z,i,t} > 0 & (14) \\ 0, & \text{if} \quad \text{otherwise} & (15) \end{cases}$$

---

[8]Survey data evidence summarized in Fabiani et al. (2006) show that firms in the Euro area mostly set prices according to some mark-up rules.

where (δ) is the firms' share of net profits distributed as dividends. The last thing firms do is to evaluate their accumulated profits. If they do not distribute all the net profits in dividends, then they accumulate profits and receive interest on them (see subsection 3.4). Firms accumulated profits are define as:

$$\pi_{z,i,t}^{ac} = \pi_{z,i,t-1}^{ac} + (1-\delta)\pi_{z,i,t}^{n} \qquad (16)$$

3.4. The Financing of the Firm

In the present model, firms not only produce goods and invest in R&D but also interact with a generic banking system by taking out loans to finance their negative cash flow (negative profit). If a firm has negative gross profit it will have to finance it by taking out a loan on the amount of the negative gross profit. The loan operation lasts one period, if an indebted firm generates positive net profit greater than its debt, then it will write the debt off. If the profit is not enough to pay for the entirety of its debt the firm will use all of it to pay as much as possible of the debt. In the later case, the firm still pays interest on the remaining debt on the next period. In the case that the firm does not obtain any profit a new loan is taken out and the firms debt increases. Therefore firms debts are given by:

$$debt_{z,i,t} = \begin{cases} debt_{z,i,t-1} + \pi_{z,i,t}^{g}, & \text{if} \quad \pi_{z,i,t}^{g} < 0 & (17) \\ debt_{z,i,t-1} - \pi_{z,i,t}^{g}, & \text{if} \quad 0 < \pi_{z,i,t}^{g} < debt_{z,i,t-1} & (18) \\ 0, & \text{if} \quad \pi_{z,i,t}^{g} > debt_{z,i,t-1} & (19) \end{cases}$$

If a firm had a positive debt in the past period, on period t it will have to pay an interest rate i^l on it. In this case, the firm will have financial expenses given by:

$$fin_{z,i,t}^{exp} = i^l debt_{z,i,t-1} \qquad (20)$$

In the opposite scenario, were a firm accumulates profits, it receives financial revenues on its undistributed or accumulated part of net profit. In this case, firms receive financial revenues according to:

$$fin_{z,i,t}^{rev} = i^d \pi_{z,i,t-1}^{ac} \qquad (21)$$

3.5. Technological Progress and Productivity

In the present model, technical progress or innovation is limited to the process of process innovation[9]. It is known that if one assumes non-linear Engel curves with income elasticities less than one for the aggregate of existing products, the consumption ratio of an economy is bound to fall continuously in the absence of new products, which means that, the rise in per-capita income due to technical progress on the production side is not accompanied by a similarly rise in demand, leading to under-consumption (Frey, 1969). Under-consumption may lead to generalized unemployment in the economy.

In order avoid too much under-consumption and to keep the model simple, the consumers' satiation limit increases with the increase in their income (see subsection 3.6). Once technical change is taken into account, technological improvements that raise labour productivity will affect firms' profitability as they affect unit labour costs and, therefore, the firms' competitiveness. Technological progress, in

---

[9]There is a vast literature that shows that the introduction of new consumer products is a necessary condition for economic progress in a market economy, Andersen (2001); Aoki and Yoshikawa (2002); Saviotti (2001); Saviotti and Pyka (2008); Foellmi and Zweimüeller (2008).

this model, results from investment on R&D. At the beginning of each period each firm invests a fraction ($\phi \in (0, 1]$) of its past sales ($s_{z,i,t-1}$) on R&D[10], so that:

$$rd_{z,i,t} = \phi s_{z,i,t-1} \tag{22}$$

R&D expenses are paid to the same workers that produce the goods. This is a rather strange way to model innovation, however makes the model much simpler. Each worker is a production worker and a researcher at the same time.

Even though innovation depends on R&D expenses, it is a highly uncertain process. Therefore, in the present model this process is set as a two stages stochastic event (e.g. Aghion and Howitt (1998); Silverberg and Verspagen (2005)). In the first stage, there is the event "success or failure" in the discovery of a new technology, while in the second stage there is the event of increasing labour productivity. In the first stage, the probability ($\rho_{z,i,t}$) of success in discovering a new technology depends not only on the amount of financial resources devoted to it but also on the parameter ζ (Nelson and Winter, 1982; Valente and Andersen, 2002; Llerena and Lorentz, 2004):

$$\rho_{z,i,t} = 1 - e^{-\zeta rd_{z,i,t}} \tag{23}$$

R&D investment is successful when a random number from a uniform distribution ($[0; 1]$) is smaller than ($\rho_{z,i,t}$). In this case, the firm's productivity may increase according to a value extracted from a normal distribution centred on its current productivity (Ciarli, 2012):

$$a_{z,i,t} = a_{z,i,t-1}(1 + max\{\varepsilon_{z,i,t}; 0\}) \tag{24}$$

where $\varepsilon_{z,i,t} \sim N(0; \psi_{z,i,t})$ is a normally distributed random function. The higher the $\psi_{z,i,t}$ the larger the potential productivity increase. We refer to this parameter as the productivity shock. The productivity shock does not only differs across sectors but also varies across time and firms:

$$\psi_{z,i,t} = \frac{\sigma_z^a}{(a_{z,i,t-1})^{\xi_z}} \qquad \text{with} \qquad \xi_z \in [0; 1] \tag{25}$$

where (σ_z^a) is the initial productivity shock. The initial productivity shock differs across sectors and is in part responsible for generating different sectoral averages productivities and consequently the relative price effect in the economy. According to equation (25), the larger the past productivity level the smaller the productivity shock in the case of a successful innovation. The parameter (ξ_z) adjusts the size of the effect of past productivity to the productivity shock. When set to 0, past productivity has no effect on the productivity shock, which is in turn still determined randomly, but now from a normal distribution with constant standard deviation given by (σ_z^a).

3.6. Consumers' Demand

The present model's demand side follows is built based on a simple non-homothetic hierarchical demand where consumers spend their income according to given priorities as in Falkinger (1990, 1994) and Andersen (2001). This demand structure establishes that any consumer wants to consume a satisfactory (satiation) level of one good, if available, before consuming anything of the next good in the hierarchy. This notion of consumption hierarchy is also described by Pasinetti (1981, 1993). According to him, consumption is ultimately governed by a generalised version of Engel's Law. The generalised law says that the consumption of any (basic category of) good cannot be expanded beyond its satiation level. Furthermore, when consumption of a good has become satiated, attention

---

[10]The literature indicates that R&D growth is caused by growth in sales rather than profits (Dosi et al., 2006; Coad and Rao, 2010).

turns to the next higher good in the hierarchical ordering of goods according to their importance in consumption (Andersen, 2001).

Consumption begins after firms have set their prices and paid their workers. Each individual (h) is a worker, a consumer and also a shareholder at the same time, which means that, individuals consume out of their wealth (wh), which is composed of wages, payment received for R&D (rd_t^r), savings ($sav_{h,t}$) and dividends received (div_t^r). For simplicity, the number of individuals (N^h) in the economy is fixed and each individual offers the same amount of labour hours in the market (H^{wj}). Firms do not hire individuals *per se*, they hire labour hours, which means that a worker might work for different firms. In the model this is not a problem as we assumed that all firms in all sectors pay the same wage rate (w_t^r). Moreover, in order to simplify the analysis all the individuals receive the same income, that is, the wage bill of all firms is summed together and divided by the number of individuals in the economy[11]. One of the consequences of this mechanism is that when unemployment rises, nobody receives zero income, but everybody receives less income. The same mechanism is applied to payments for R&D and in the distribution of dividends, everyone in the economy receives the same amount. Thus:

$$wh_{h,t} = w_t^r + rd_t^r + div_t^r + sav_{h,t-1} \qquad h = [1, 2...N^h] \tag{26}$$

where:

$$w_t^r = \frac{\sum_{z=1}^{3} \sum_{i=1}^{N_{z,t}^F} wb_{z,i,t}}{N^h} \qquad rd_t^r = \frac{\sum_{z=1}^{3} \sum_{i=1}^{N_{z,t}^F} rd_{z,i,t}}{N^h} \qquad div_t^r = \frac{\sum_{z=1}^{3} \sum_{i=1}^{N_{z,t}^F} div_{z,i,t}}{N^h}$$

Individuals' wealth may differ due to differences in their savings ($sav_{h,t}$). For the sake of simplicity, individuals do not save as a conscious decision. Saving is a the result of not being able to buy all the units desired of all the goods due to supply shortages, or having more resources than enough to buy the satiation quantity for all of the three goods. Thus, individual savings is given by:

$$sav_{h,t} = sav_{h,t-1} + (wh_{h,t} - exp_{h,t}) \tag{27}$$

where ($exp_{h,t}$) is each individual's total expenditure on all three goods.

Individuals have to determine their satiation level for each sector/good before start spending. For simplicity, individuals satiation level varies across goods and time but not across individuals. Recent empirical works on Engel curves (Moneta and Chai, 2010; Chai and Moneta, 2012, 2014; Moneta and Chai, 2014) show that absolute demand saturation rarely occurs and that non-saturation is a more frequent outcome, even if more complex Engel curves are observed in a number of cases. Therefore, in order to avoid absolute satiation, satiation level is initially set at ($sat_{z,0}$) and increases with increases in income-per-capita (y) according to:

$$sat_{z,t} = sat_{z,t-1}[1 + \eta_z(\ln(y_t) - \ln(y_{t-1}))] \tag{28}$$

where (η_z) is the good's satiation level growth coefficient. Since (η_z) differs across sectors, demand becomes non-homothetic. The income-per-capita (y) is given by:

$$y_t = w_t^r + rd_t^r + div_t^r \tag{29}$$

---

[11]This might seen too socialist to some, however our intention here is just to simplify the model avoiding income dispersion among workers and among employed and unemployed individuals.

Once prices, satiation level and income-per-capita are determined consumption takes place. The first consumer goes to the goods market and observes the prices charged by a random subset of $(k = (1, ... \chi))$ firms from sector 1 (agriculture). He orders this subset of (χ) firms by price, from the cheapest to the most expensive and goes to the firm that charges the lowest price first. His expenditure on good 1 is given by:

$$
exp_{h,1,t} = \begin{cases}
sat_{1,t}p_{1,k,t}, & \text{if} & wh_{h,t} \geq sat_{1,t}p_{1,k,t} & \text{and} & xs_{1,k,t} \geq sat_{1,t} & (30a) \\
xs_{1,k,t}p_{1,k,t}, & \text{if} & wh_{h,t} \geq sat_{1,t}p_{1,k,t} & \text{and} & xs_{1,k,t} < sat_{1,t} & (30b) \\
wh_{h,t}, & \text{if} & wh_{h,t} < sat_{1,t}p_{1,k,t} & \text{and} & xs_{1,k,t} \geq wh_{h,t}/p_{1,k,t} & (30c) \\
xs_{1,k,t}p_{1,k,t}, & \text{if} & wh_{h,t} < sat_{1,t}p_{1,k,t} & \text{and} & xs_{1,k,t} < wh_{h,t}/p_{1,k,t} & (30d)
\end{cases}
$$

In cases (30b) and (30d), the consumer is still left with money to consume. In these cases the consumer moves to the next cheapest firm and executes the same routine. The consumer continues until he exhausts his resources, reaches his satiation point, or finishes his list of (χ) selected firms. After executing the routine for good 1 (agriculture), if there is money left the consumer goes to good 2 (manufacturing) and executes the same routine, and then to good 3 (service). If after consuming the three goods the consumer still have resources left, he saves them for the next period. The effective consumption is always bound by the real production of the consumption-good sector.

3.7. Aggregate and Averaged Variables

The wage rate (w_t) is determined by the growth of the economy's average productivity level:

$$
w_t = w_{t-1}[1 + (\ln(A_t) - \ln(A_{t-1}))] \tag{31}
$$

where (A) is the economy's average productivity level, which is a weighted average of sectoral productivity level (SA), with the weight being the share of sector employment (SL) in total employment (L). The average of sectoral productivity level is given by the weighted average of the firms productivity level within each sector. The weight used is the firms' market share given by:

$$
ms_{z,i,t} = \frac{x_{z,i,t-1}}{SX_{z,t-1}} \tag{32}
$$

where (SX) is the sector's total production in units, calculated as as:

$$
SX_{z,t} = \sum_{i=1}^{N_{z,t}^F} x_{z,i,t} \tag{33}
$$

Sector employment (SL) is calculate as:

$$
SL_{z,t} = \sum_{i=1}^{N_{z,t}^F} l_{z,i,t} \tag{34}
$$

4. Simulation and Results

We ran 50 Monte Carlo simulations[12] of the model. The model is able to generate endogenous growth and structural change. The results of our simulations shows that the model is able to replicate some interesting patterns and empirical regularities.

---

[12]Each simulation lasts 550 time steps. The first 50 time steps were not analysed as they are used to adjust the parameters.

First of all, as Caselli (2005) observes, the reasons for poor countries' poverty is strongly related to their productivity in the agricultural sector and with the share of the working population employed in that sector. (Gollin et al., 2002) reports that there is a positive relationship between the growth in a country's agricultural productivity and the movement of labour out of agriculture. The model was able to replicate this empirical observation as we can see on Figure (2f).

Figures (2a), (2b) and (2c) show the correlation between the sectors employment and value added shares and the growth of GDP per capita (represented in log). This patterns were reported by Herrendorf et al. (2014) (see Figure (1)). Herrendorf et al. (2014) observes that over the last two centuries, increases in GDP per capita have been associated with decreases in both the employment share and the nominal value added share in agriculture, and increases in both the employment share and the nominal value added share in services.

Another interesting regularity reported by Herrendorf et al. (2014), is that for low levels of development, the value added share is considerably lower than the employment share in the agricultural sector. This regularity was also replicated by the model as we can see on Figure (2a). In our model, this difference is in part due to a substantial difference between the wage and the productivity in the agricultural sector. Workers in agriculture receive 60% less than their productivity. The parameter ν_z is responsible for this adjustment in the wage rate (see Table (A.1)).

Regarding the manufacturing sector, empirical studies have reported that manufacturing employment and nominal value added shares follow a hump shape, that is, they are increasing for lower levels of development and decreasing for higher levels of development (Herrendorf et al., 2014). This pattern can be seen on Figure (2b) with relation to income-per-capita and on Figure (2d) across time.

One of the striking features of developed economies is the large size of their service sector. According to some early works, such as Fisher (1935) and Clark (1940), the income-elasticity for services (which were considered luxuries) is greater than one. Therefore, as income-per-capita grows, the share of goods in overall demand will decline and that of services will rise. Because services rank higher in the hierarchy of needs, countries would allocate more resources to services as their incomes grow and consequently wealthier countries would have a higher share of service demand and of service employment. Following this hypothesis, today's share of service industry employment is higher than in the past because societies demand more services (Schettkat and Yocarini, 2006). Moreover, since the productivity in the service sector is in general low, the sector tends to absorb most of the labour force in developed economies. Fourastié and Siegfried (1949) saw in low productivity growth of services the hope for employment.

Buera and Kaboski (2012) and Herrendorf et al. (2014) observe that the nominal value added share for manufacturing peaks around the same log GDP at which the nominal value added share for the service sector accelerates, so it appears that the accelerated increase in the value added share of services coincides with the onset of the decrease in the value added share for manufacturing sector. Furthermore, (Buera and Kaboski, 2012) also reports that at low levels of GDP per capita the manufacturing sector expands more quickly than does the service sector. Both regularities were also replicated by the model, as we can see on Figure (2d).

The dynamics of some of the aggregate variables can be seen on Figures (3a), (3b), (3c) and (3d). One striking result is how the economy's GDP growth rate follows the same trend as the average productivity growth. As the economy's income-per-capita increases, labour is shifted towards the service sector and the average productivity tends to fall. This is the result of a much lower average productivity in the service sector than in the other two sectors, see Figure (2e).

Unfortunately, due to lack of space we are unable to report the microeconomic results and dynamics generated by the mode.
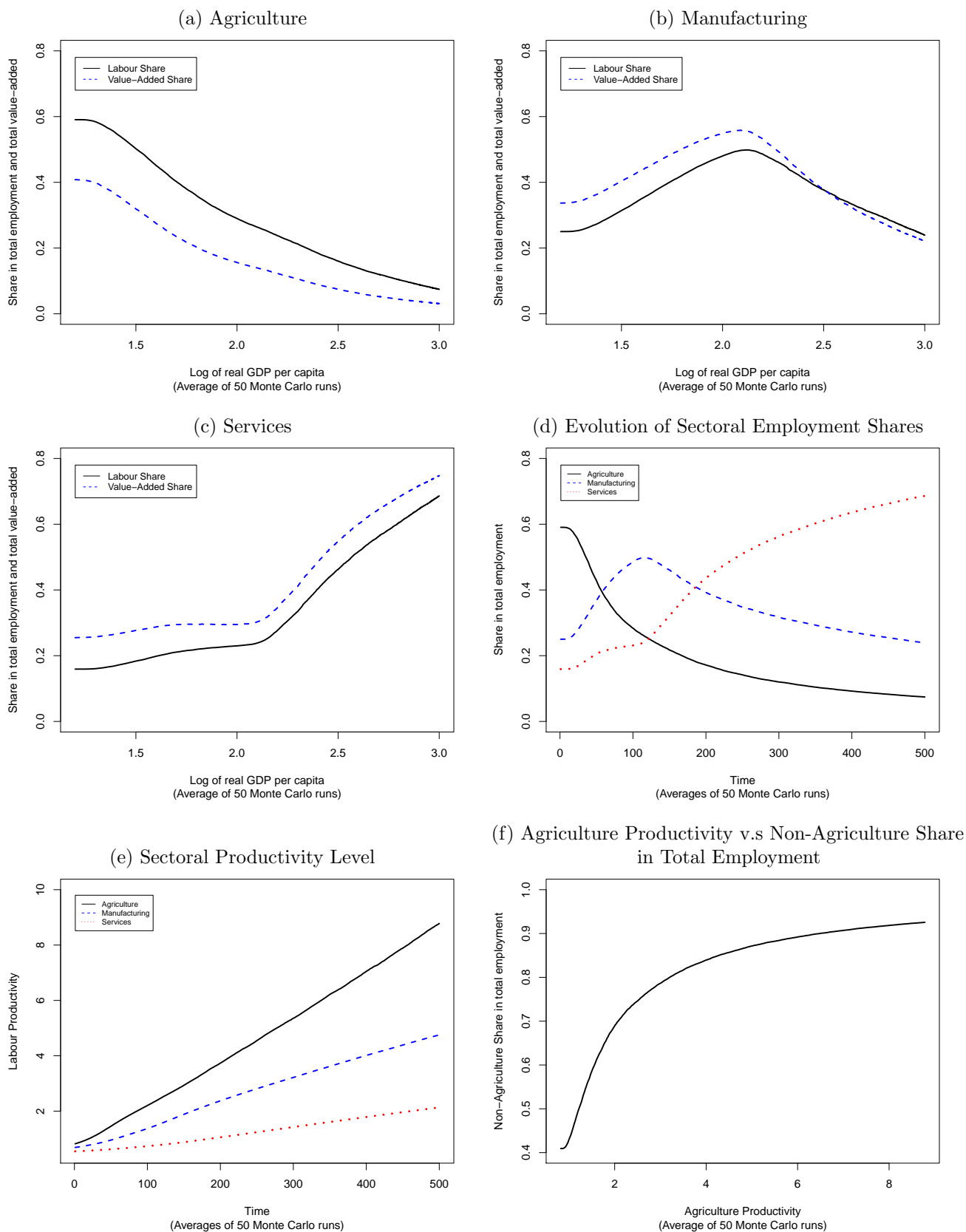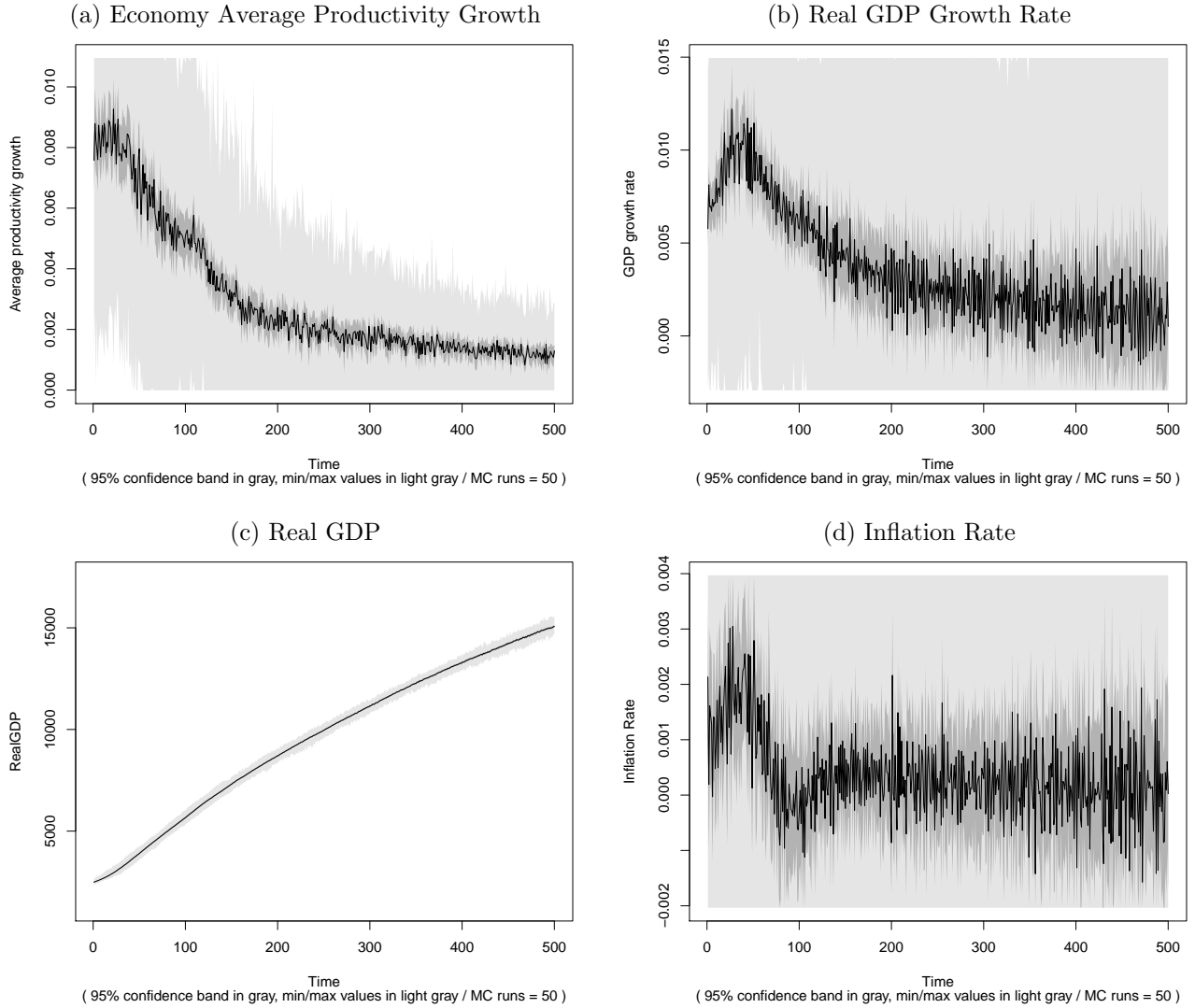
Figure 2: Sectoral Dynamics

(a) Agriculture

(b) Manufacturing

(c) Services

(d) Evolution of Sectoral Employment Shares

(e) Sectoral Productivity Level

(f) Agriculture Productivity v.s Non-Agriculture Share in Total Employment

Figure 3: Aggregate Variables Evolution

(a) Economy Average Productivity Growth

Time
(95% confidence band in gray, min/max values in light gray / MC runs = 50)

(b) Real GDP Growth Rate

Time
(95% confidence band in gray, min/max values in light gray / MC runs = 50)

(c) Real GDP

Time
(95% confidence band in gray, min/max values in light gray / MC runs = 50)

(d) Inflation Rate

Time
(95% confidence band in gray, min/max values in light gray / MC runs = 50)

5. Concluding Remark

Economists still struggle to understand why some countries are so much richer than others. The shift of labour out of the agricultural sector into other such sectors as manufacturing and services is one important piece of this puzzle. It is known that poor countries have lower labour productivity in agriculture, lower labour productivity outside agriculture and a larger share of employment in the agricultural sector that – on average – is less productive. Structural change and economic growth and development are strongly interconnected. Therefore, understanding not only the driving mechanisms and forces behind the process of structural change but also how these mechanisms interact and reinforce each other is crucial.

The model developed in the present article is able to theoretically replicate the dynamics of structural change where labour is reallocated across the three macro-sectors of agriculture, manufacturing and services. The process of structural change is driven by demand and supply factors simultaneously, as sectors differ in their income elasticities of demand and in their productivity growth rates. As we have discussed, the literature offers several explanations for the process of structural change, some based on the income effect and others on the relative-price effect. These two types of effects are often presented as competing mechanisms. Our model demonstrates that, given certain assumptions regarding agents' behaviour, the two mechanisms are not competing but actually complementaries and must coexist in order to replicate the kind of labour and value-added structural change observed in the data.

Our model can be extended in several directions. Three extensions are most promising. First, while the model assumes a fixed number of goods, the introduction of a process of product creation within each macro-sector would enrich the analysis by allowing the reallocation of labour not only across the three macro-sectors but also within them. Second, while our analysis has assumed a uniform income distribution, the introduction of heterogeneous labour were workers receive different incomes is potentially interesting, as the existence of rich and poor households with different consumption bundles would open up a new channel by which income inequality could affect growth and structural change. Third, so far our analysis have focused on a closed economy, the next natural step would be to consider how hierarchic preferences and product specialization in a world economy would affect the process of structural change and growth.

References

Acemoglu, D. and Guerrieri, V. (2008). Capital Deepening and Nonbalanced Economic Growth. *Journal of Political Economy*, 116(3):467–498.

Aghion, P. and Howitt, P. (1998). *Endogenous Growth Theory*. The MIT Press, Cambridge, Massachusetts.

Alvarez-Cuadrado, F. and Poschke, M. (2011). Structural Change Out of Agriculture: Labor Push versus Labor Pull. *American Economic Journal: Macroeconomics*, 3(3):127–158.

Andersen, E. S. (2001). Satiation in an evolutionary model of structural economic dynamics. *Journal of Evolutionary Economics*, 11(1):143–164.

Aoki, M. and Yoshikawa, H. (2002). Demand saturation-creation and economic growth. *Journal of Economic Behavior & Organization*, 48(2):127–154.

Baumol, W. J. (1967). Macroeconomics of Unbalanced Growth: An Anatomy of Urban Crisis. *American Economic Review*, 55:297–307.

Boppart, T. (2014). Structural Change and the Kaldor Facts in a Growth Model With Relative Price Effects and Non-Gorman Preferences. *Econometrica*, 82(6):2167–2196.

Broadberry, S., Campbell, B. M., and van Leeuwen, B. (2013). When did Britain industrialise? The sectoral distribution of the labour force and labour productivity in Britain, 1381-1851. *Explorations in Economic History*, 50(1):16–27.

Buera, F. J. and Kaboski, J. P. (2012). Scale and the origins of structural change. *Journal of Economic Theory*, 147(2):684–712.

Caselli, F. (2005). Accounting for Cross-Country Income Differences. In Aghion, P. and Durlauf, S. N., editors, *Handbook of Economic Growth*, volume 1, chapter 9, pages 679–741. Elsevier.

Caselli, F. and Coleman, W. J. (2001). The U .S. Structural Transformation and Regional Convergence : A Reinterpretation. *Journal of Political Economy*, 109(3):584–616.

Chai, A. and Moneta, A. (2012). Back to Engel? Some evidence for the hierarchy of needs. *Journal of Evolutionary Economics*, 22(4):649–676.

Chai, A. and Moneta, A. (2014). Escaping Satiation Dynamics: Some Evidence from British Household Data. *Jahrbücher für Nationalökonomie und Statistik*, 234(2-3):299–327.

Chenery, H. B. (1960). Patterns of Industrial Growth. *The American Economic Review*, 50(4):624–654.

Ciarli, T. (2012). Structural interactions and long run growth: an application of experimental design to agent based models. *Observatoire Francais des Conjonctures Economiques Revue*, 124:295–345.

Ciarli, T. and Lorentz, A. (2010). Product Variety and Changes in Consumption Patterns: The Effects of Structural Change on Growth. *13th Conference of the International Schumpeter Society, Alborg University*.

Ciarli, T., Lorentz, A., Savona, M., and Valente, M. (2010). The Effect of Consumption and Production Structure on Growth and Distribution: A Micro to Macro Model. *Metroeconomica*, 61(1):180–218.

Ciarli, T. and Valente, M. (2016). The complex interactions between economic growth and market concentration in a model of structural change. *Structural Change and Economic Dynamics*, 38:38–54.

Clark, C. (1940). *The Conditions of Economic Progress*. McMillan & Co, London.

Coad, A. and Rao, R. (2010). Economics of Innovation and New Technology Firm growth and R&D expenditure Firm growth and R&D expenditure. *Economics of Innovation and New Technology*, 19(2):127–145.

Deaton, A. and Muellbauer, J. (1980). *Economics and consumer behavior*. Cambridge University Press, Cambridge-USA.

Dennis, B. N. and İşcan, T. B. (2009). Engel versus Baumol: Accounting for structural change using two centuries of U.S. data. *Explorations in Economic History*, 46(2):186–202.

Dosi, G., Marengo, L., and Pasquali, C. (2006). How much should society fuel the greed of innovators?. On the relations between appropriability, opportunities and rates of innovation. *Research Policy*, 35(8 SPEC. ISS.):1110–1121.

Echevarria, C. (1997). Changes in Sectoral Composition Associated with Economic Growth. *International Economic Review*, 38(2):431–452.

Engel, E. (1857). Die Produktions-und Consumtionsverhaltnisse des Konigreichs Sachsen. *Zeitschrift des Statistischen Bureaus des Koniglich Sachsischen Ministeriums des Innern*, pages 1–54.

Fabiani, S., Druant, M., Hernando, I., Kwapil, C., Landau, B., Loupias, C., Martins, F., Math, T., Sabbatini, R., Stahl, H., and Stokman, A. (2006). What Firms' Surveys Tell Us about Price-Setting Behavior in the Euro Area. *International Journal of Central Banking*, 2:3–47.

Falkinger, J. (1990). On growth along a hierarchy of wants. *Metroeconomica*, 41(3):209–223.

Falkinger, J. (1994). An Engelian model of growth and innovation with hierarchic consumer demand and unequal incomes. *Ricerche Economiche*, 48(2):123–139.

Fischer, A. G. B. (1939). Primary, Secondary and Tertiary Production. *Economic Record*, 15(June):24–38.

Fisher, A. G. B. (1935). *Clash of progress and security*. Macmillan and Co. Limited, London.

Foellmi, R. and Zweimüeller, J. (2008). Structural Change, Engel's Consumption Cycles and Kaldor's Facts of Economic Growth. *Journal of Monetary Economics*, 55(7):1317–1328.

Foster, A. D. and Rosenzweig, M. R. (2007). Economic Development and the Decline of Agricultural Employment. In Schultz, P. T. and Strauss, J. A., editors, *Handbook of Development Economics*, volume 4, chapter 47, pages 3051–3083. Elsevier.

Fourastié, J. and Siegfried, A. (1949). *Le grand espoir du XXe siècle: progrès technique, progrès économique, progrès social*. Presses universitaires de France, Paris.

Frey, B. (1969). Product and Process Innovations in Economic Growth. *Zeitschrift für Nationalökonomie / Journal of Economics*, 29:29–38.

Gabardo, F. A., Pereima, J. B., and Einloft, P. (2017). The incorporation of structural change into growth theory: A historical appraisal. *EconomiA*, 18(3):392–410.

Gollin, D., Parente, S., and Rogerson, R. (2002). The Role of Agriculture in Development. *The American Economic Review*, 92(2):160–164.

Gräbner, C. (2016). Agent-based computational models– a formal heuristic for institutionalist pattern modelling? *Journal of Institutional Economics*, 12(1):241–261.

Herrendorf, B., Rogerson, R., and Valentinyi, Á. (2014). Growth and Structural Transformation. In *Handbook of Economic Growth*, volume 2, chapter 6, pages 855–941. Elsevier.

Kaelble, H. (1997). Der Wandel der Erwerbsstruktur in Europa im 19. und 20. Jahrhundert. *Historical Social Research*, 22:5–28.

Kongsamut, P., Rebelo, S., and Xie, D. (2001). Beyond Balanced Growth. *The Review of Economic Studies*, 68(4):869–882.

Krüger, J. J. (2008). Productivity and structural change: a review of the literature. *Journal of Economic Surveys*, 22(2):330–363.

Kuznets, S. (1957). Quantitative Aspects of the Economic Growth of Nations: II. Industrial Distribution of National Product and Labor Force. *Economic Development and Cultural Change*, 5(4):1–111.

Kuznets, S. (1973). Modern Economic Growth: Findings and Reflections. *The American Economic*

Review, 63(3):247–258.

Laitner, J. (2000). Structural Change and Economic Growth. *The Review of Economic Studies*, 67(3):545–561.

Llerena, P. and Lorentz, A. (2004). Cumulative Causation and Evolutionary Micro-Founded Technical Change. *Revue économique*, 55(6):1191.

Lorentz, A., Ciarli, T., Savona, M., and Valente, M. (2016). The effect of demand-driven structural transformations on growth and technological change. *Journal of Evolutionary Economics*, 26(1):219–246.

Lorentz, A. and Savona, M. (2008). Evolutionary Micro-dynamics and Changes in the Economic Structure. *Journal of Evolutionary Economics*, 18:389–412.

Maddison, A. (1987). Growth and Slowdown in Advanced Capitalist Economies: Techniques of Quantitative Assessment. *Journal of Economic Literature*, 25(2):649.

Matsuyama, K. (1992). Agricultural productivity, comparative advantage, and economic growth. *Journal of Economic Theory*, 58:317–334.

Matsuyama, K. (2008). Structural Change. In Durlauf, S. N. and Blume, L. E., editors, *The New Palgrave Dictionary of Economics*. Palgrave McMillan UK, second edition.

Moneta, A. and Chai, A. (2010). Retrospectives: Engel Curves. *Journal of Economic Perspectives*, 24(1):225–240.

Moneta, A. and Chai, A. (2014). The evolution of Engel curves and its implications for structural change theory. *Cambridge Journal of Economics*, 38(4):895–923.

Nelson, R. R. and Winter, S. (1982). *An evolutionary theory of economic change.* Harvard University Press, Cambridge.

Ngai, L. R. and Pissarides, C. A. (2007). Structural Change in a Multisector Model of Growth. *The American Economic Review*, 97(1):429–443.

Pasinetti, L. L. (1981). *Structural change and economic growth.* Cambridge University Press, Cambridge.

Pasinetti, L. L. (1993). *Structural economic dinamic: A theory of the economic consequences of human learning.* Cambridge University Press, Cambridge.

Saviotti, P. P. (2001). Variety, growth and demand. *Journal of Evolutionary Economics*, 11(1):119–142.

Saviotti, P. P. and Pyka, A. (2008). Product variety, competition and economic growth. *Journal of Evolutionary Economics*, 18(3-4):323–347.

Schettkat, R. and Yocarini, L. (2006). The shift to services employment: A review of the literature. *Structural Change and Economic Dynamics*, 17(2):127–147.

Silva, E. G. and Teixeira, A. A. C. (2008). Surveying structural change: Seminal contributions and a bibliometric account. *Structural Change and Economic Dynamics*, 19(4):273–300.

Silverberg, G. and Verspagen, B. (2005). Evolutionary theorizing on economic growth. In Dopfer, K., editor, *The Evolutionary Foundations of Economics*, pages 506–539. Cambridge University Press, Cambridge.

Syrquin, M. (1988). Patterns of structural change. In *Handbook of Development Economics*, volume 1, chapter 7, pages 203–273. Elsevier.

Valente, M. and Andersen, E. S. (2002). A Hands-on Approach to Evolutionary Simulation: Nelson and Winter Models in The Laboratory for Simulation Development. *The Eletronic Journal of Evolutionary Modeling and Economic Dynamics*.

Appendix A.

Table A.1: Sectoral Parameters and Initial conditions

Symbol	Description	Agriculture	Manufacturing	Services
N_z^F	Number of Firms	25	25	25
ζ	Innovation probability adjustment coefficient	1	1	1
ξ_z	Productivity shock alleviation	0.5	1.2	1.2
λ_D	Expected Demand adaptive expectations coefficient	0.25	0.25	0.25
η_z	Satiation level growth coefficient	0.05	0.35	0.7
ν_z	Sectoral wage rate adjustment coefficient	0.4	0.8	1
ϕ	R&D investment propensity over past sales	0.01	0.01	0.01
γ_L	Labour hiring rigidity coefficient	0.006	0.006	0.006
σ^μ	Mark-up adjustment coefficient	0.001	0.001	0.001
σ^a	Initial productivity Shock	0.05	0.05	0.005
a	Initial labour productivity	0.5	0.5	0.5
C_{max}	Initial Maximum Household Consumption (units)	5	5	5
uc	Initial Unit Cost	1	1	1
μ	Initial mark-up	0.05	0.05	0.05
SX	Initial Total Sector Production (units)	1750	750	500
L	Initial Total Labour Demand (hours)	3500	1500	1000
W	Initial Total Wage Paid (MU)	1750	750	500
$sat_{z,0}$	Initial satiation level	5	5	5
P_0	Initial Prices	1	1	1

Table A.2: Aggregate Initial Conditions

Symbol	Description	Value
N^h	Number of Households	750
i^l	Interest rate on loans	0.01
i^d	Interest rate on deposits	0.01
δ	Firms' net profits' share distributed as dividends	1
H^{wj}	Household work journey	8
χ	Number of firms that consumers consult before byuing	3
w	Initial wage rate	0.5
y	Initial income per capita	4
u_0	Initial unemployment	0