A STUDY ON THE SKILL PREMIUM AND INFORMALITY

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ABSTRACT

A Study on the Skill Premium and Informality

Skill premium as defined by the ratio of the skilled labor wage to the unskilled labor wage is said to be explained by the relative labor ratio and the equipment-skill ratio. In this paper, the relation between the skill premium and the size of the informal sector is observed and a positive relation has been found, based on the regression results. A dynamic stochastic general equilibrium model is also set up in order to observe the relation between these variables. According to the model results, a higher skill premium occurs when the size of the informal sector is lower. Although it seems contradictory to the regression results, it is believed to be associated with the higher level of output produced in the low informal sector case. The effect of the informal sector size on the way skill premium is affected by productivity shocks is observed and it has been found that a greater size of informal sector causes skill premium to be affected more from the neutral productivity shocks. On the other hand, a lower level of informal sector causes skill premium to be affected more from the investment-specific productivity shocks.

ÖZET

Vasıf Primi ve Kayıtdışı Ekonomi Üzerine bir Çalışma

Vasıflı işgücü ücretinin vasıfsız işgücü ücretine oranı olarak tanımlanmış olan vasıf priminin, vasıfsız işgücünün vasıflı işgücüne oranı ve sermaye ekipmanının vasıflı işgücüne oranı kullanılarak açıklanabileceği çeşitli çalışmalarda gösterilmiştir. Bu çalışmada vasıf priminin kayıtdışı ekonomi ile ilişkisi gözlemlenmiş ve yapılan regresyon sonuçlarına göre iki değişken arasında pozitif bir ilişki bulunmuştur Ayrıca, söz konusu iki değişken arasındaki ilişkinin gözlemlenebilmesi için dinamik stokastik genel denge modeli oluşturulmuştur. Model sonuçlarına göre, daha düşük kayıtdışı ekonomi seviyesinde daha yüksek vasıf primi oluşmaktadır. Bu sonuç regresyon sonuçlarıyla çelişiyor gibi görünse de, bu durumun düşük seviyede kayıtdışı ekonominin varlığında daha fazla çıktı oluşmasıyla ilgili olduğu düşünülmektedir. Bu çalışmada ayrıca, kayıtdışı ekonomi büyüklüğünün vasıf priminin şoklardan etkilenmesine etkisi incelenmiş ve daha yüksek seviyede kayıtdışı ekonominin varlığının vasıf priminin nötral üretkenlik şoklarından daha fazla etkilenmesine sebep olduğu gözlemlenmiştir. Diğer taraftan, daha düşük seviyede bir kayıtdışı ekonominin ise vasıf priminin yatırım odaklı üretkenlik şoklarından daha fazla etkilenmesine sebep olduğu gözlemlenmiştir.

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CHAPTER 1

INTRODUCTION

Labor market structures in both the United States and Europe have long been a crucial research area for economists, where income inequality attracts significant attention. Skill premium as the ratio of skilled labor wage to unskilled labor wage is one of the indicators of income inequality. Many studies confirm that skill premium has increased excessively in the post-war period both in the United States (Katz and Murphy,1992, Acemoglu and Autor, 2011, Krusell et al., 2000) and Europe (Goos et al., 2010, Michaels et al., 2009). In these studies, it is commonly observed that the relative supply of the skilled labor increased in the observed period. Despite the increase in the supply of skilled labor, it is observed that the skill premium increases which seems contradictory at first glance. Because it is expected that the price of the relatively abundant factor to fall and reduce the skill premium. The observed increase in the skill premium is mostly attributed to demand-side effects. The increasing demand for skilled labor could be seen by observing the changes in education and experience differentials. Katz and Murphy (1992) show that education and experience differentials increase remarkably in the observed period. Besides that, structural change in the labor market, which results in a decrease in middle-skill jobs and polarization of employment in upper and lower segments of skills and wages, is another reason causing the rise in demand for skilled labor (Acemoğlu and Autor, 2011).

The common result of these studies is that the rise in the population of skilled labor relative to unskilled labor in the post-war period cannot explain the rise in the skill premium if the factors affecting the demand for the skill group are not

considered. Katz and Murphy (1992) show that changes in the ratio of labor inputs mostly explain the rise in the skill premium when a time trend (KM time trend) is used as a proxy for the increasing demand for the skilled labor depending on the advances in new technologies.

Griliches (1969) introduces capital-skill complementarity to the literature, in order to explain the rise in the skill premium despite increasing supply of skilled labor. After Griliches (1969), Krusell et al. (2000) use capital-skill complementarity as the underlying variable behind KM time trend and propose a model where observed variables could explain the rise in the skill premium. The model proposed by Krusell et al. (2000) uses a neoclassical production function which consists of four types of production factors which are capital structures, capital equipment, skilled labor and unskilled labor. In the model, capital equipment and skilled labor are complementary to each other whereas unskilled labor is a substitute for capital equipment. Following Krusell et al. (2000), Lindquist (2004) and Lindquist (2005) empirically show that capital-skill complementarity is important in explaining the rise in the skill premium in the United States (Lindquist, 2004) and Sweden (Lindquist, 2005).

Lindquist (2005) asserts that there are three types of effects in the literature that are said to be the reasons for the observed changes in the skill premium. These are supply-side effects, demand-side effects and institutional effects; where skill-biased technological change is in the demand side. Lindquist (2005) uses the model developed by Krusell et al. (2000), to explain the income inequality in Sweden. Although institutional effects are dominant in the literature for explaining the wage dispersion in Sweden, Lindquist (2005) shows that the neoclassical framework in

Krusell et al. (2000) could also explain some part of the movements in the wages of the skilled and unskilled workers in Sweden.

Lindquist (2005) decomposes the changes in the skill premium into two effects: capital-skill complementarity and relative quantity effect and shows that the capital-skill complementarity is important in explaining the rise in the skill premium. He also shows that, if it is allowed that the growth rates of efficiency of labor skills to be different from zero, then relative efficiency effect also explains some part of the changes in the skill premium. Nevertheless capital-skill complementarity still preserves its importance in this setting.

On the other hand, Lindquist (2004) shows that capital-skill complementarity has a positive effect on the skill premium, by regressing the skill premium on the ratio of capital equipment to skilled labor and the ratio of unskilled labor to skilled labor where the former ratio is a proxy for the capital-skill complementarity. After showing that the relative labor ratio and the equipment-skill ratio could explain the skill premium, Lindquist (2004) sets up a dynamic stochastic general equilibrium model based on the model used by Krusell et al. (2000). Using the model, he observes how these variables are affected by productivity shocks and finds out that the consumption, investment, output, and working hours all have positive and immediate responses to neutral productivity shock, while investment-specific productivity shock's immediate impact is only to increase the working hours and consequently the output. Following that, consumption decreases and savings from the increased output are used to increase the investment in capital equipment. He also observes that the equipment-skill ratio increases in both cases, whereas the relative labor ratio increases following neutral productivity shock but decreases following investment-specific productivity shock.

In this paper, we will use a similar model used in Lindquist (2004) to observe the effect of the informal sector's presence on the economy's response to the productivity shocks. Considering the literature about the skill premium and capital-skill complementarity, we see that the ratio of labor inputs together with the capital equipment to skilled labor ratio, which is a proxy for capital-skill complementarity, is important in explaining the path that skill premium has followed in the last decades. On the other hand, we also think that the presence of a larger informal sector also affects the way skill premium is affected by productivity shocks.

The informal sector is defined as the part of the economy "where firms and workers produce legal, market-based goods and services but . . . circumvent government regulations." by Shapiro (2013) (p. 14). In developing countries, 60% of the workforce producing nearly 40% of the GDP is employed in the informal sector, according to Ihrig and Moe (2004). In the literature, informality is generally associated with weak institutional quality. On the other hand, some of the studies in the literature point out that the informal sector absorbs the shocks since informal firms can adapt to the conditions better than formal firms because of having lower costs. (Bosch and Maloney: 2006).

In this study, we question the relation between the informal sector and the skill premium. For this purpose, in Chapter 2, we first use a panel data set consisting of 15 countries and 13 years. Using this dataset, we set up a regression in which the skill premium is regressed on the relative labor ratio, the equipment-skill ratio and the informal sector size. From the regression, we observe that all the independent variables in the regression, including the informal sector size, have a positive relation to the skill premium. Following that in Chapter 3, we extend the model used in Lindquist (2004) by adding an informal sector with a production function similar to

the one used in Ihrig and Moe (2004) and Elgin and Oztunali (2012). Our model results show that the steady state values of the skill premium is higher in the lower informal sector cases. This might seem contradictory to the regression results at first sight; however, lower informal sector size also brings about a higher output produced and higher marginal product for the skilled labor. The equipment-skill ratio and the relative labor ratio are also higher when the size of the informal sector is lower. So, a higher skill premium is a composite result of changes in all these variables. On the other hand, the regression results show the relation between the informal sector size and the skill premium for the given levels of the labor input ratios. So, the presence of the informal sector might represent low quality institutions, lower bargaining power of the workers or any other reason, which could be a topic for further research.

After finding the steady states, we observe the effect of informality on the way skill premium is affected by productivity shocks and observe that both shocks positively affect the skill premium. When the economy is hit by a neutral productivity shock, equipment-skill ratio increases in both high and low informal sector size cases. However, the presence of higher informal sector causes a higher rise in the skill premium which is because of the higher rise in relative labor ratio. The response of the equipment-skill ratio to the investment-specific productivity shock is also positive. However, skill premium increases more in the lower informal sector case because of the lower fall in the relative labor ratio. The investment-specific productivity shock causes a greater increase in the skilled labor working hours compared to the unskilled labor working hours. As a result of this, the relative labor ratio falls following investment-specific productivity shock and this fall is greater in high informal sector case, which results in a lower skill premium. The sensitivity of the model results are controlled in Chapter 4, by changing some of the

parameter values used in the model in Chapter 3. After observing that the model results are robust to the changes in parameters, the study is concluded in Chapter 5.

CHAPTER 2

EMPIRICAL ANALYSIS

A panel data set for 15 countries and 13 years is created in order to observe the relation between the informal sector size and the skill premium. It consists of data for the skill premium, informal sector size, equipment-skill ratio, and the relative labor ratio. For the calculation of the skill premium, total hours worked per year and total earnings per year for workers at different skill levels are used from Quality Adjusted Labor Input (QALI) dataset. Lindquist (2004) defines the skilled labor as the workers with 14 years or more of education, whereas Krusell et al. (2000) define as the workers with 16 years or more of education. In the QALI dataset, high-skilled labor is defined as workers with at least first to second stages of tertiary education. Medium-skilled labor is defined as workers with upper secondary to post-secondary and non-tertiary education. Low-skilled labor is defined as pre-primary to lower secondary education. In this paper, we categorize these three types of workers in QALI data set as unskilled and skilled labor, by consolidating low-skilled and medium-skilled workers as unskilled workers. For the informal sector size, we use the ratio of the output produced in the informal sector to the output produced in the formal sector, which was created by Elgin and Oztunali (2012).

Figure 1 shows the skill premium data for 15 countries and 13 years. Skill premium for these 15 countries varies between 1.27 and 2.35. For most of the countries, it starts to fall after 2002. Denmark, Finland, and the United Kingdom are the countries with the lowest skill premium, whereas Luxembourg, Slovenia and Austria are the countries with the highest skill premiums, if the average skill premium values are compared.

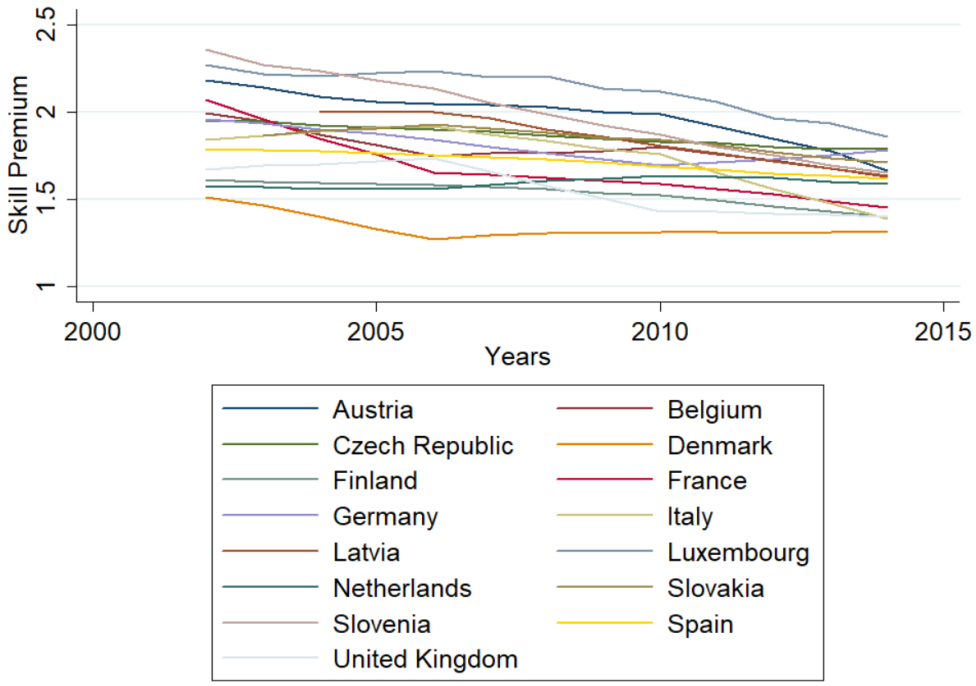

Figure 1. Skill premium: Panel data set for 15 countries and 13 years

The informal sector size data is shown for the same period and the same countries in Figure 2, for which the skill premiums are shown in Figure 1. The informal sector size in these countries changes between 9 percent and 28 percent and does not change remarkably. Latvia, Italy and Spain are the countries with the highest informal sector sizes, whereas the United Kingdom, Austria, and Luxembourg are the countries with the lowest informal sector sizes, if the average informal sector sizes are compared.

Griliches (1969), Krusell et al. (2000) and Lindquist (2004) show that the relative labor ratio and the capital-skill complementarity are successful in explaining the skill premium's historical path. Lindquist (2004) also shows that the skill premium is positively related with the relative labor ratio and the equipment-skill ratio, which is a proxy for capital-skill complementarity. In this paper, we extend this regression by adding the size of the informal sector as another independent variable.

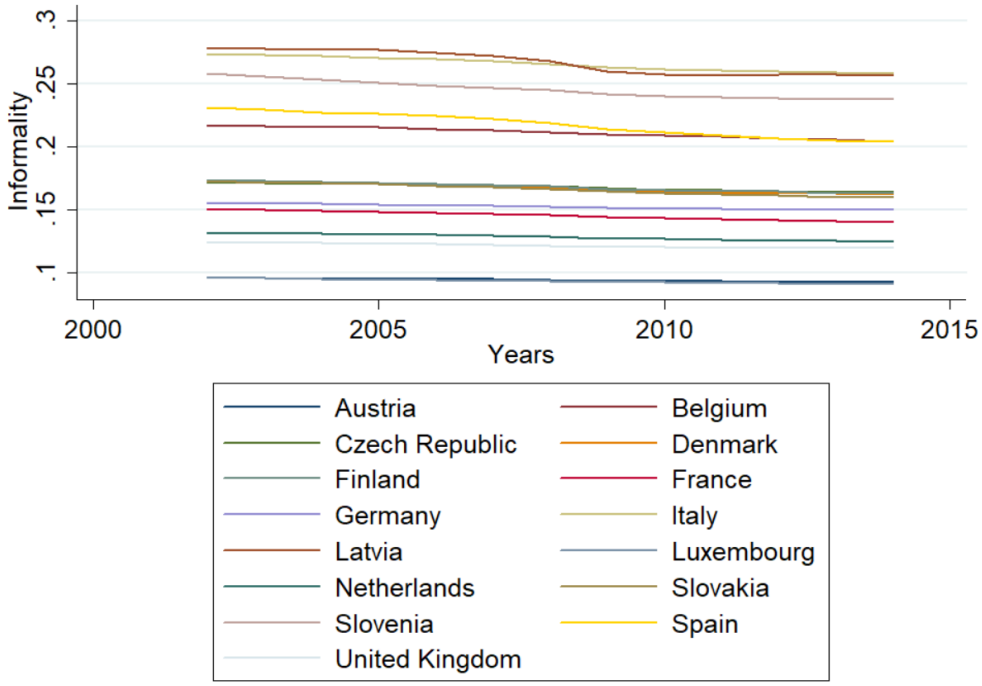

Figure 2. Informal sector size: Panel data set for 15 countries and 13 years

By doing this, we are aiming to observe the relation between the informal sector size and the skill premium. The corresponding regression equation is the following:

$$Skill\ premium = \beta_0 + \beta_1 \frac{H_u}{H_s} + \beta_2 \frac{K_e}{H_s} + \beta_2 \frac{Y_I}{Y_F}$$

The first independent variable in the regression is the ratio of unskilled labor working hours to skilled labor working hours, which we extract from the QALI data set. We use the same categorization for the skilled and unskilled labor types, which we use for the generation of skill premium data. The second independent variable is the equipment-skill ratio for which the capital equipment data is needed in addition to the skilled labor working hours. We use capital services data from EU KLEMS data set for the capital equipment. The last variable is the ratio of the output produced in the informal sector to the output produced in the formal sector, where we use the data created by Elgin and Oztunali (2012) as used in Figure 2. The dependent variable of the regression, skill premium, is created from QALI data set as explained previously

in this chapter. By using the coinciding parts of all these data, we create a panel dataset for 15 countries and 13 years from 2002 to 2014.

The results of the benchmark regression are shown in the column (1) of Table 1. We tried both random effects and fixed effects regression and decided to use fixed effects regression by applying the Hausman test to the results. When we look at these results, we see that all three of the independent variables are positively associated with skill premium and all coefficients are statistically significant. The positive relation between the skill premium and the relative labor ratio is intuitive in the sense that the higher number of unskilled labor population makes unskilled labor cheaper, because of simple supply demand relation. On the other hand, the positive and statistically significant coefficient for the equipment-skill ratio supports the capital-skill complementarity hypothesis which has attracted considerable attention in the literature for explaining the skill premium's historical path. As the equipment-skill ratio increases, the marginal product of the skilled labor is also expected to increase because of skill complementarity of the capital equipment. Assuming that the workers get their marginal products as their wages, a rise in the marginal product of the skilled labor could be related to the rise in the skill premium.

As could be observed from the results, the size of the informal sector has a positive relation to the skill premium and the positive coefficient for this variable is also significant. One percent increase in the size of the informal sector is followed by a 0.08797 increase in the skill premium. For the given levels of the equipment-skill ratio and the relative labor ratio, higher/lower informal sector size is related to a higher/lower level of skill premium. However, the positive relation between the informal sector size and skill premium might be dependent on some other factors which has been omitted in the regression.

Table 1. Regression Results

Dependent Variable: Skill Premium	(1)	(2)	(3)	(4)	(5)
Equipment-skill ratio	734.52 (387.41)*	685.56 (385.75)*	991.43 (338.80)***	981.52 (335.65)**	976.58 (336.99)***
Relative labor ratio	0.084 (0.017)***	0.082 (0.017)***	0.074 (0.024)***	0.08 (0.024)***	0.076 (0.024)***
Informal sector size	8.797 (2.067)***	9.212 (2.067)***			
Rule of law		-0.144 (0.072)***		0.098 (0.087)	
Government effectiveness		0.107 (0.081)*			
Informal sector size[1]			13.057 (3.171)***	12.388 (3.195)***	
Informal sector size[2]					12.594 (3.168)***
Constant	-0.054 (0.326)	0.085 (0.333)	-0.782 (0.499)	-0.821 (0.495)*	-0.709 (0.498)
R^2	0.547	0.512	0.589	0.6	0.59
F-Test	62.83***	48.57***	48.06***	47.54***	48.53***

1 Instrumental variables used for informal sector size: Rule of law, capital stock, total tax and contribution rate
2 Instrumental variables used for informal sector size: Government effectiveness, capital stock, total tax and contribution rate

In column (2) of Table 1, the rule of law and the government effectiveness are also added to the regression. The data for the rule of law and government effectiveness is from the dataset created for The Worldwide Governance Indicators Project of the World Bank. It has been found out that the rule of law has a negative and significant coefficient whereas the coefficient for the government effectiveness is positive and significant. In columns (3) and (4) of Table 1, rule of law, capital stock and total tax and contribution rate have been used as instrumental variables for informal sector. All the coefficients are positive and significant in columns (3) and (4), except the rule of law in column (4). The data source for the capital stock is Penn World Tables 9.1, whereas the data source for the total tax and contribution rate is the World Bank,

Doing Business Project. Lastly, in column (5) of Table 1, government effectiveness has been used as an instrumental variable instead of rule of law and the remaining variables are the same with column (3). The resulting coefficients are positive and significant in this case.

The positive sign of the coefficient for the informal sector size does not turn out to be negative in any one of the cases which might also be controlled in other studies by using a dataset of greater size. In the following chapters of this study, we will be more interested in the effect of informality on factor input ratios and the skill premium, when the economy is hit by productivity shocks.

CHAPTER 3

THEORETICAL FRAMEWORK

In this chapter, we construct a dynamic stochastic general equilibrium model based on the model used by Krusell et al. (2000) and Lindquist (2004). Our model is an extended version of this model by the addition of the informal sector by using the production function used in Ihrig and Moe (2004) and Elgin and Oztunali (2012).

In our model, the formal sector utilizes capital structures (K_{s_t}) and capital equipment (K_{e_t}) in production and employs both skilled and unskilled labor, whereas the informal sector does not use any form of capital but employs unskilled labor. The skilled and the unskilled workers have the same utility function where they get utility from the consumption of the goods produced in the economy and from the hours of leisure they have. The unskilled workers allocate their working time between the formal ($h_{u_{f_t}}$) and the informal sectors ($h_{u_{i_t}}$), whereas skilled workers work only in the formal sector (h_{s_t}). Hours of leisure for the skilled and unskilled workers are represented by l_{s_t} and l_{u_t}, respectively and each worker has one unit of time that can either be spent for leisure or work.

$$h_{s_t} = 1 - l_{s_t}$$

$$h_{u_{f_t}} + h_{u_{i_t}} = 1 - l_{u_t}$$

The general form of the utility function for these workers is as follows, where c_{i_t} represents the quantity of the consumption goods and $\mathrm{l}_{\mathrm{i}_\mathrm{t}}$ represents the time spent for leisure.

$$U_{i_t}(c_{i_t}, l_{i_t}) = \frac{\left(c_{i_t}^{\alpha} l_{i_t}^{1-\alpha}\right)^{1-\rho} - 1}{1-\rho}, \qquad 0 < \alpha < 1, \qquad \rho \geq 0.$$

In this economy, total population of workers equals to 1 ($u + s = 1$), where u and s are the unskilled and skilled workers' populations respectively. The population of the unskilled workers in the formal sector is denoted by u_f and the population of the unskilled workers in the informal sector is denoted by u_i, where $u_f + u_i = u$. H_{s_t} and $H_{u_{f_t}}$ are aggregate labor hours worked in the formal sector, by skilled and unskilled workers respectively. $H_{u_{i_t}}$ shows the aggregate labor hours worked in the informal sector by unskilled workers. Aggregate labor hours for both skilled and unskilled workers working in both sectors are calculated as follows:

$$H_{s_t} = sh_{s_t}$$

$$H_{u_{f_t}} = u_{f_t} h_{u_{f_t}}$$

$$H_{u_{i_t}} = u_{i_t} h_{u_{i_t}}$$

The production function for the formal sector that utilizes the capital structures, capital equipment, skilled labor and the unskilled labor is shown below:

$$G\left(K_{s_t}, K_{e_t}, H_{s_t}, H_{u_{f_t}}\right) = e^{z_t} K_{s_t}^{\theta} \left[\mu H_{u_{f_t}}^{v} + (1-\mu)(\lambda K_{e_t}^{\varphi} + (1-\lambda) H_{s_t}^{\varphi})^{v/\varphi}\right]^{(1-\theta)/v}$$

$$\theta, \mu, \lambda \in (0,1), \quad v, \varphi \in (-\infty, 1),$$

The function exhibits capital skill complementarity when $v > \varphi$. z_t and q_t are the stochastic technology variables in the production function, where z_t is the neutral technology term, and q_t is investment-specific technology term. Equations that determine the stochastic technology variables z_t and q_t are as follows:

$$z_t = \rho_z z_{t-1} + \varepsilon_{z_t}$$

$$q_t = \rho_q q_{t-1} + \varepsilon_{q_t}$$

ε_{z_t} and ε_{q_t} are drawn from a bivariate normal distribution as in Lindquist (2004)

$$\varepsilon_z \sim N(\mu_z, \sigma_z^2)$$

$$E[\mu_z] = 0$$

$$(\varepsilon_q, \varepsilon_z) \sim N\left[(\mu_q - \eta\mu_z) + \eta\varepsilon_z, \bar{\omega}^2\right]$$

K_{e_t} and K_{s_t} are aggregate capital equipment and aggregate capital structures respectively and depreciate at rates δ_e and δ_s. Investments to capital equipment and capital structures are denoted by X_e and X_s respectively. The laws of motion for capital equipment and capital structures are as follows:

$$K_{e_{t+1}} = (1 - \delta_e)K_{e_t} + X_{e_t}e^{q_t}$$

$$K_{s_{t+1}} = (1 - \delta_s)K_{s_t} + X_{s_t}$$

The production function of the informal sector has only unskilled labor as the production factor and κ is the deterministic neutral technology term for this sector.

$$F\left(H_{u_{i_t}}\right) = \kappa H_{u_{i_t}}^{\gamma}$$

The formal and the informal sectors produce the same type of consumption good. Goods produced in the formal and informal sectors are consumed by all the skilled and unskilled workers, where $C_{s_t} = sc_{s_t}$, $C_{u_t} = uc_{u_t}$. The informal sector is not subject to taxation whereas formal firms pay taxes as the proportion (τ) of the output they produced. Taxes collected by the government are assumed to be spent for nonproductive services by the government (Ihrig and Moe: 2004).

If this economy was managed by a benevolent social planner, who discounts future utilities by β and gives Ψ and (1- Ψ) weights to utilities of each type of worker, the social planner's problem for this economy would be as follows:

$$\max_{\{c_{s_t}, c_{u_t}, h_{s_t}, h_{u_{f_t}}, h_{u_{i_t}}, K_{s_{t+1}}, K_{e_{t+1}}\}} E_0 \sum_{t=0}^{\infty} \beta^t \{(1 - \Psi)\mathrm{uU}(c_{u_t}, l_{u_t}) + \Psi\mathrm{sU}(c_{s_t}, l_{s_t})\}$$

$$subject\ to$$

$$C_{s_t} + C_{u_t} + X_{s_t} + X_{e_t} = (1 - \tau)G(K_{s_t}, K_{e_t}, H_{s_t}, H_{u_t}) + F(H_{u_t}),$$

and the Lagrangian function for the social planner's problem is:

$$\mathcal{L}\left(K_{s_t}, K_{e_t}, c_{s_t}, c_{u_t}, h_{s_t}, h_{u_{f_t}}, h_{u_{i_t}}, \lambda_{1_t}, \lambda_{2_t}, \lambda_{3_t}\right) =$$

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{(1-\Psi)\mathrm{u}\frac{\left(c_{u_t}^{\alpha}(1-h_{u_{f_t}}-h_{u_{i_t}})^{1-\alpha}\right)^{1-\rho}-1}{1-\rho} + \Psi\mathrm{s}\frac{\left(c_{s_t}^{\alpha}(1-h_{s_t})^{1-\alpha}\right)^{1-\rho}-1}{1-\rho}\right\} -$$

$$E_0 \sum_{t=0}^{\infty} \beta^t \lambda_{1_t} \begin{Bmatrix} C_{s_t} + C_{u_t} + K_{s_{t+1}} - (1-\delta_s)K_{s_t} + \frac{K_{e_{t+1}}}{e^{q_t}} - \frac{(1-\delta_e)K_{e_t}}{e^{q_t}} \\ -(1-\tau)G\left(K_{s_t}, K_{e_t}, H_{s_t}, H_{u_{f_t}}\right) - F\left(H_{u_{i_t}}\right) \end{Bmatrix} -$$

$$E_0 \sum_{t=0}^{\infty} \beta^t \lambda_{2_t} \left\{z_t - \rho_z z_{t-1} - \varepsilon_{z_t}\right\} - E_0 \sum_{t=0}^{\infty} \beta^t \lambda_{3_t} \left\{q_t - \rho_q q_{t-1} - \varepsilon_{q_t}\right\}$$

3.1 Model calibration

The model parameter values are calibrated by using Eurostat and QALI databases when there is available data. The dataset created by Elgin and Oztunali (2012) is also used for calibration. Some of the parameters used are from Krusell et al. (2000), Lindquist (2004), Lindquist (2005) and Atesagaoglu and Elgin (2015) studies.

Following Lindquist (2004), we assume that the skilled workers constitute 47 percent of the population in the economy, which he calibrates by using MORG dataset. In this model, unskilled workers work both in formal and informal sectors, so we need the proportion of unskilled workers in the formal and informal sectors. In order to do this, we use Elgin and Oztunali (2012) dataset consisting of 159 countries and 65 years. This dataset gives us the output ratio of the informal sector to the formal sector for each year and country. We find the average level of the informal sector for each country and rank them from the lowest to the highest and use the informal sector sizes at the 10th and 90th percentiles in order to represent countries with low and high levels of the informal sector sizes, respectively. We assume that the proportion of the unskilled workers in the informal sector equals the proportion of informal sector output to the formal sector output. With this assumption, we

multiply the proportion of the unskilled workers in the economy, with the ratio of informal sector size to the formal sector size and find the unskilled workers in the informal sector. The remaining part of the unskilled workers is assumed to be working in the formal sector, which we parameterize by u_f. So, if we use the value at the 10th percentile u_f becomes 0.429, it means most of the unskilled workers work in the formal sector and the informal sector size is small. On the other hand, if we use the value at the 90th percentile u_f becomes 0.254, it means that a significant number of workers work in the informal sector and the informal sector size is high in this economy.

The remaining parameters in Table 2 are from Krusell et al. (2000), Lindquist (2004), Lindquist (2005) and Domeij and Ljungvist (2019). Lindquist (2004), Lindquist (2005) and Domeij and Ljungvist (2017) use the model created by Krusell et al. (2000), where Lindquist (2005) and Domeij and Ljungvist (2017) focus on Sweden and calibrate some of the parameters which do not fit to Sweden. For both

Table 2. Parameters

Parameter	Value	Source	Parameter	Value	Source
s	0.47	Lindquist (2004)	θ	0.17	Lindquist (2004), Domeij and Ljungvist (2019)
u_f *	Low:0.429 High:0.254		μ	0.413	Lindquist (2004)
β	0.9875	Lindquist (2004)	λ	0.553	Lindquist (2004)
ψ	0.589	Lindquist (2004)	φ	-0.9344	Lindquist (2005)
α	0.611	Lindquist (2004)	ν	0.2873	Lindquist (2005)
ρ	1	Lindquist (2004)	κ	0.78	Atesagaoglu and Elgin (2005)
δ_s	0.014	Lindquist (2004)	γ	0.425	Atesagaoglu and Elgin (2005)
δ_e	0.031	Lindquist (2004)	τ	0.295	Atesagaoglu and Elgin (2005)

* u_f is calibrated by using the dataset created by Elgin and Öztunalı (2012).

high and low informal sector size cases the same parameters in Table 2 are used, and the model is run two times in Dynare for the two levels of formal and informal sector sizes. The sensitivity of the model to the parameter changes will be checked in Chapter 4.

3.2 Steady state results

The model is log-linearized around steady-state values and the relevant decision rules are acquired for the economy. Table 3 shows the steady state values of the model for low and high informal sector cases.

Table 3. Steady State Results for Low and High Informal Sector Cases

	Low Informal Sector	High Informal Sector		Low Informal Sector	High Informal Sector
c_s	0.52	0.51	y_f	1.44	1.17
c_u	0.37	0.35	y_i	0.17	0.35
c	0.89	0.86	y_i/y_f	0.12	0.30
h_{u_f}	0.30	0.11	w_s	0.38	0.29
h_s	0.42	0.26	w_{u_f}	0.34	0.33
h_{u_i}	0.18	0.38	w_{u_i}	0.34	0.33
h	0.90	0.75	w_s/w_{u_f}	1.12	0.87
k_e	1.04	0.57	k_e/h_s	1.56	1.39
k_s	2.47	1.13	h_{u_f}/h_s	0.71	0.35
k	3.51	1.69			

The model results show that the steady state skill premium is higher in the low informal sector case. Also, steady state values for the output, capital equipment, capital structures, working hours for both types of workers in the formal sector, equipment-skill ratio, and the relative labor ratio are all higher in the low informal sector case. Comparing these results with the literature and with the regression results in Chapter 2, we see the same positive relation between the skill premium and

the factor input ratios. However, the relation between the informal sector size and the skill premium seems to contradict with our regression results.

In order to check the validity of our argument by which we claim a positive relationship between the informal sector size and the skill premium, we generated 50 different steady state values for 50 levels of informal sector size by changing the parameter, u_f, between 0.254 and 0.429. The positive relation between the factor input ratios and the skill premium and also the negative relation between the skill premium and the informal sector size in Table 3 still holds looking at these 50 steady states in Figures 3, 4 and 5.

On the other hand, we find a positive relation between the informal sector size and the skill premium in the regression, when the factor input ratios are included in the regression. In order to explain the difference between the model results and the regression results, we also need to consider other factors, which could possibly affect the relation between the informal sector size and the skill premium. For this purpose, in Figures 6 and 7, we look at the relations of the equipment-skill ratio and the relative labor ratio with the size of the informal sector and see that both ratios are

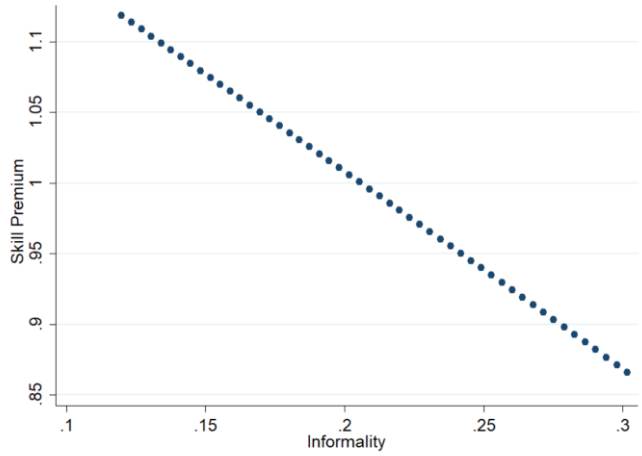

Figure 3. Steady state values: Skill premium vs. informality

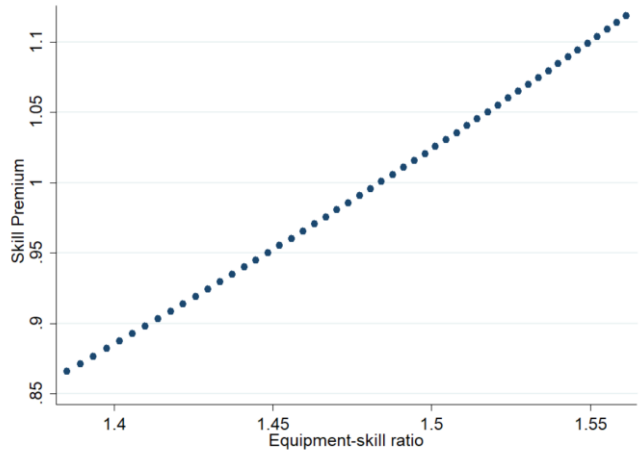

Figure 4. Steady state values: Skill premium vs. equipment-skill ratio

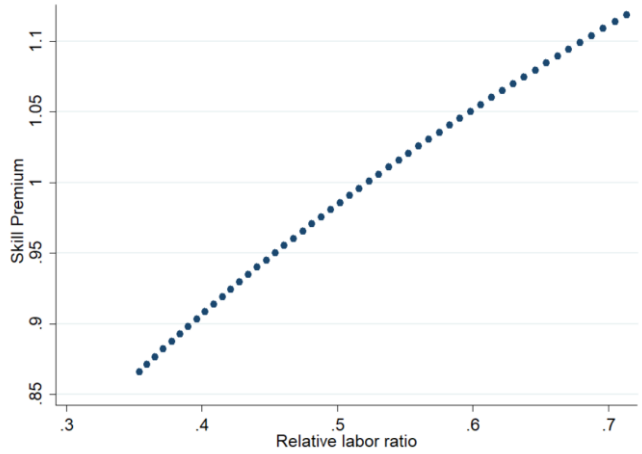

Figure 5. Steady state values: Skill premium vs. relative labor ratio

negatively associated with the informality. These relations might actually explain the negative relation between the skill premium and the informality, such that a lower level of informal sector is associated with a higher level of skill premium probably since a lower level of informal sector is related to a higher level of equipment-skill ratio and a higher level of relative labor ratio. So, if these effects are subtracted from the informal sector's effect on skill premium, it might be seen that the relation between the informal sector size and the level of skill premium turns out to be positive.

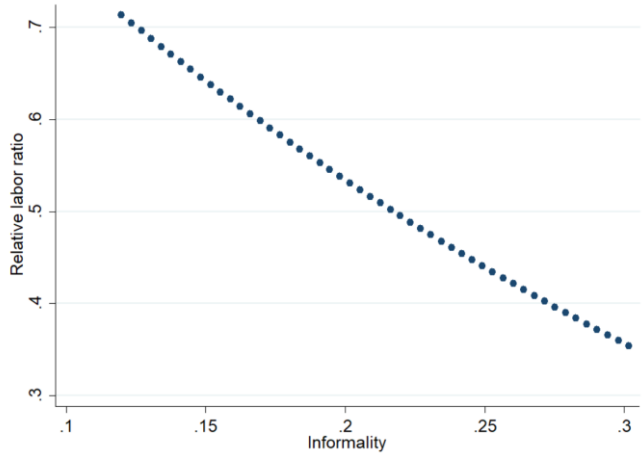

Figure 6. Steady state values: Informality vs. relative labor ratio

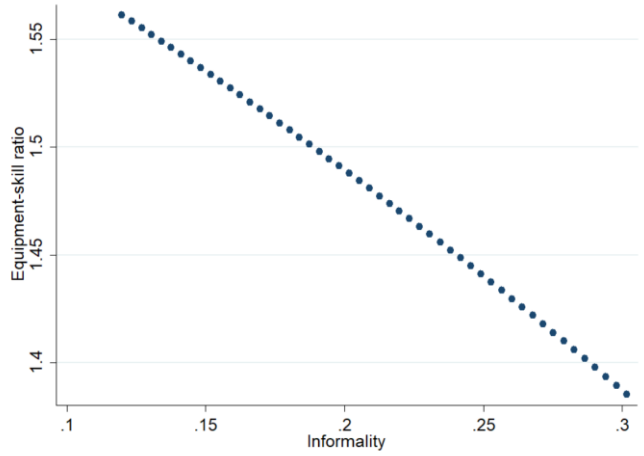

Figure 7. Steady state values: Informality vs. equipment-skill ratio

When we observe the steady states of other variables, we see that both the level of output and the capital equipment is negatively associated with the informal sector size, which can be seen in Figures 8 and 9. Formal sector as the more productive sector has a production function which exhibits capital-skill complementarity. This specialty of the production function causes formal sector to accumulate more capital and produce considerably higher output when the size of the informal sector is lower.

In figures 10 and 11, it can be seen that the marginal product of the unskilled labor in the low informal sector case is slightly higher than its high informal sector case value. On the other hand, marginal product of the skilled labor in the low

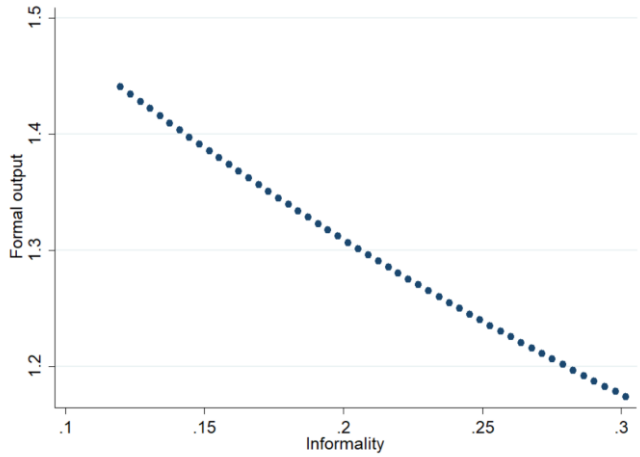

Figure 8. Steady state values: Formal output vs. informality

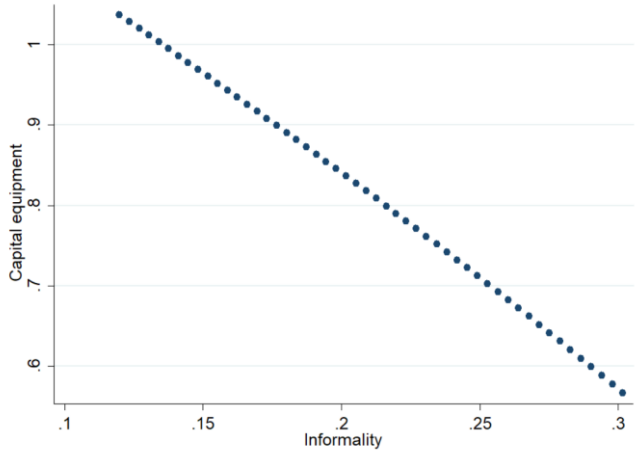

Figure 9. Steady state values: Capital equipment vs. informality

informal sector case is remarkably higher than its high informal sector case value. The remarkable difference for the skilled labor across two cases might be attributed to the capital-skill complementarity, since greater capital accumulation causes skilled labor to be favored relatively more in low informal sector case.

As a result, the low/high informal sector case ends up with a greater/lower level of output produced and the greater/lower level of capital equipment. Also, the equipment-skill ratio and the relative labor ratio are also higher in the low informal sector case. Although it seems that there is a negative relation between the skill premium and the informal sector size, what happens behind the scene is the

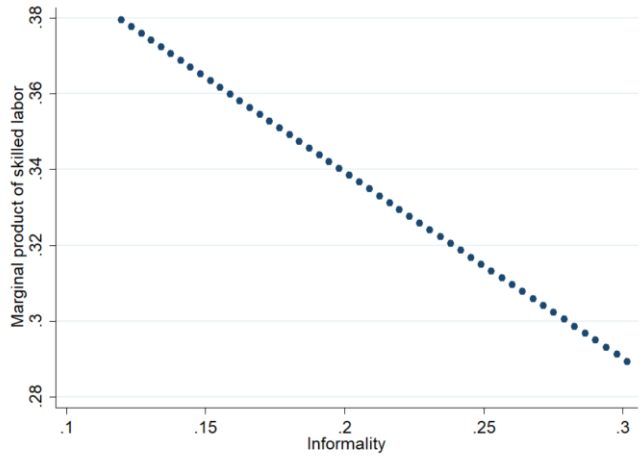

Figure 10. Steady state values: Marginal product of skilled labor vs. informality

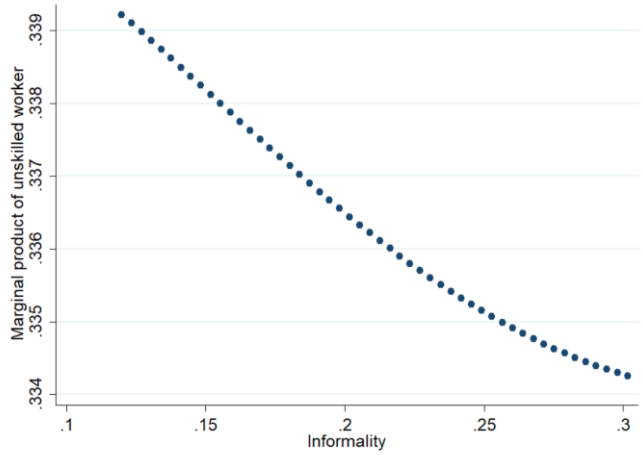

Figure 11. Steady state values: Marginal product of unskilled labor vs. informality

lower/higher factor input ratios occur in response to the higher/lower informal sector size. Even if a lower/higher level of skill premium occurs when the size of the informal sector is greater/lower, lower/higher factor input ratios might be the real cause of the lower/higher level of skill premium.

3.3 Impulse response functions

In this sub-section, what we would like to observe is the effect of informality's presence on the way skill premium is affected by the productivity shocks. For this purpose, we get impulse response functions for two different levels of informal

sector size that we calibrated in the previous sub-section. Figure 12 and Figure 13 are the impulse response functions for low and high levels of informal sector sizes, respectively, following a neutral productivity shock, whereas Figure 14 and Figure 15 are corresponding impulse response functions following an investment-specific productivity shock.

The relative labor ratio and the equipment-skill ratio are said to be positively associated with the skill premium, in the regression results in Chapter 2. Lindquist (2004) also shows the positive relation between these two ratios and the skill premium. Considering the positive relation of these ratios with the skill premium, we think that we can explain the response of the skill premium to the productivity shocks.

When we compare the relative labor ratio in the formal sector across the economies with different informal sector sizes, we see that the initial rise in this ratio is higher in the high informal sector case, which causes a higher rise in the skill premium as a first response. On the other hand, the fall in the equipment-skill ratio in both cases as a first response to the productivity shock is because of the faster response of the working hours compared to the response of the capital equipment. Working hours increase immediately with the increasing marginal product of labor, whereas capital equipment increases in time with the increase in investments. When we compare this ratio across different informal sector sizes, we see that the fall in this ratio is greater when the informal sector size is higher.

Equipment-skill ratio and relative labor ratio together explain the skill premium's response in the initial and later periods. The initial rise in the skill premium is because of the increase in relative labor ratio that overcomes the fall in equipment-skill ratio. After the initial rise, the skill premium starts to decrease with

the effect of decreasing relative labor ratio. However, the fall in skill premium does not last too long and starts to rise again with the increase in equipment-skill ratio. Comparing the impulse response functions from Figures 12 and 13, it can be said that the response of the skill premium is similar in both high and low informal sector cases, with an exaggerated response in high informal sector case.

If we look closer to the other variables to explain the differential changes in skill premium across different informality levels, we can see that the hours for both unskilled and skilled workers in the formal sector increase after the shock in both cases, with a greater rise in the higher informal sector case. When the neutral productivity shock hits the economy, the marginal products of both skilled and unskilled workers in the formal sector increase. Increase in the marginal product of workers in the formal sector causes a fall in the working hours of the workers in the informal sector that equalizes marginal products across sectors. Although this result applies to both high and low informal sector cases, the fall in the working hours of the unskilled workers in the informal sector is greater when the size of the informal sector is lower.

Consequently, the greater rise in skill premium at the initial periods, following a neutral productivity shock in the high informal sector case is mainly driven by relative labor ratio. Falling equipment-skill ratio would cause a decrease in skill premium if the effect of the relative labor ratio did not overcome its effect. Thus, we don't see the effect of capital-skill complementarity at the initial periods in this case; instead changes in the supply of labor determine the way skill premium is affected by neutral productivity shock. On the other hand, relative labor ratio falls in the later periods and the equipment-skill ratio increases dependent on the rise in investments. This causes skill premium to rise again in the later periods.

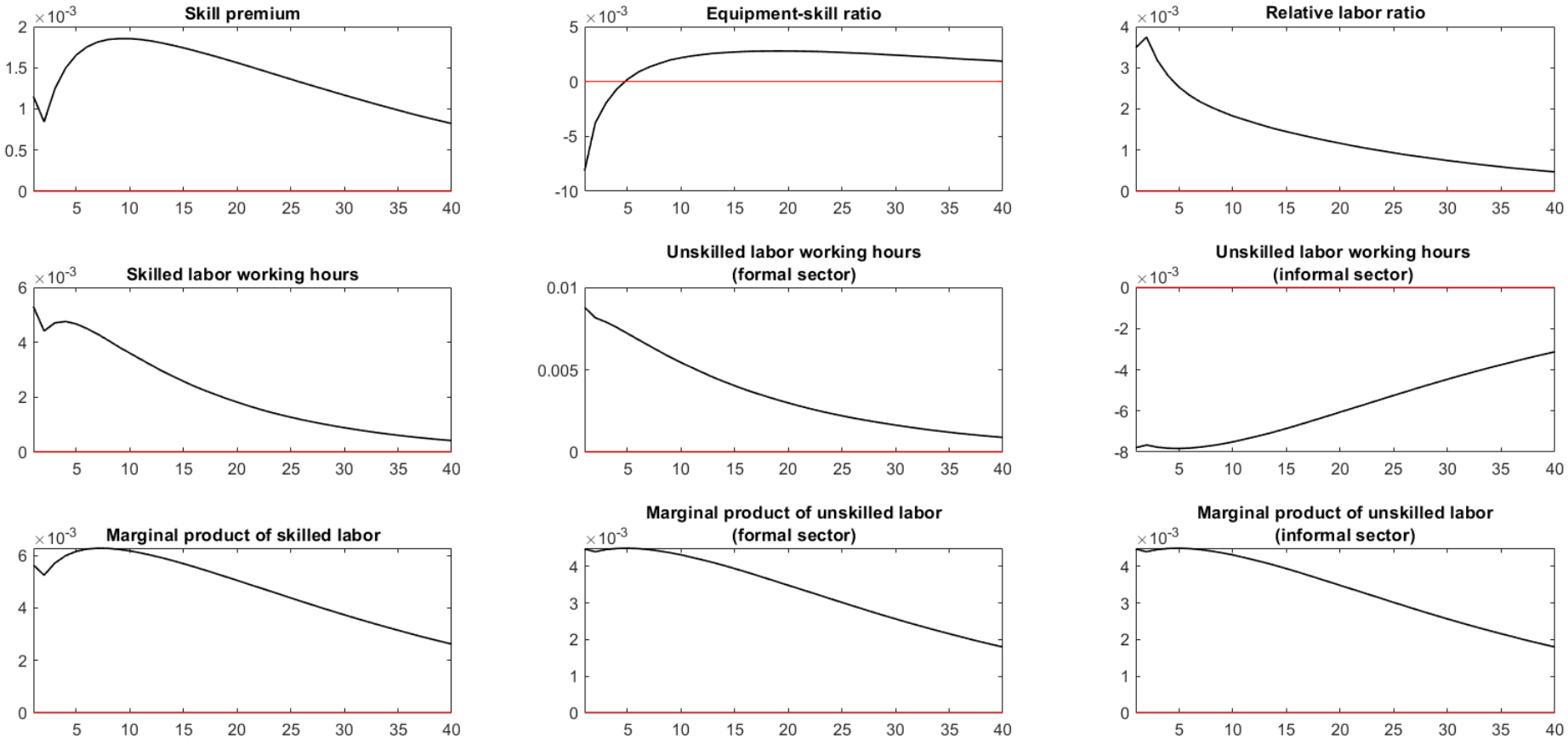

Figure 12. Impulse response functions following neutral productivity shock (low informal sector case)

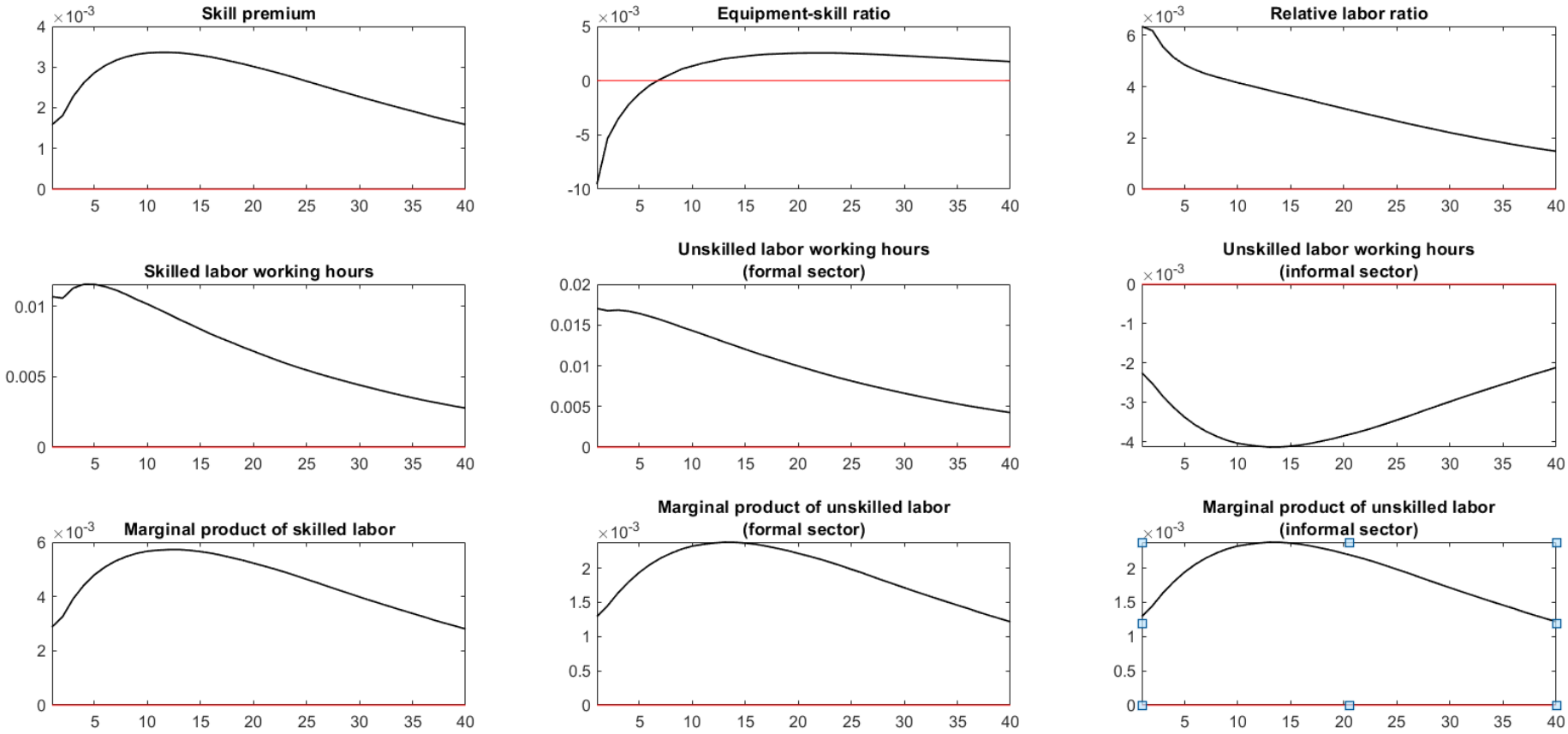

Figure 13. Impulse response functions following neutral productivity shock (high informal sector case)

Figure 14 and Figure 15 show the impulse response functions for the investment-specific productivity shock in low and high informal sector size cases, respectively. These two sets of impulse response functions jointly show that the rise in the equipment-skill ratio, as representing the capital-skill complementarity, occurs immediately following investment-specific productivity shock. The increase in this ratio, which lasts 10 to 12 periods, is much higher than the increase in the same ratio following neutral productivity shock, in percentage terms. On the other hand, relative labor ratio in the formal sector, as shown by the ratio of unskilled labor working hours to skilled labor working hours, starts to decrease following investment-specific productivity shock. As we explained in the previous chapters, equipment-skill ratio and relative labor ratio have a positive relation with the skill premium. Hence, the rise in skill premium following the shock, with an increase in equipment-skill ratio and a decrease in relative labor ratio means that the rise in equipment skill ratio overcomes the effect of relative labor ratio. However, greater fall in relative labor ratio in high informal sector case determines the difference in magnitude of the change in skill premium between two cases.

Following investment-specific productivity shock, working hours for both types of workers increase in both high and low informal sector size cases. However, the rise in the unskilled labor working hours is lower than the rise in the skilled labor working hours. Hence, the relative labor ratios fall for both of the economies, with a greater fall for the economy with higher informal sector size. The larger increase in the marginal product of skilled labor compared to the unskilled labor causes a greater rise in the skilled labor working hours, which consequently decreases the relative labor ratio in both high and low informality cases. Although the equipment-skill ratio

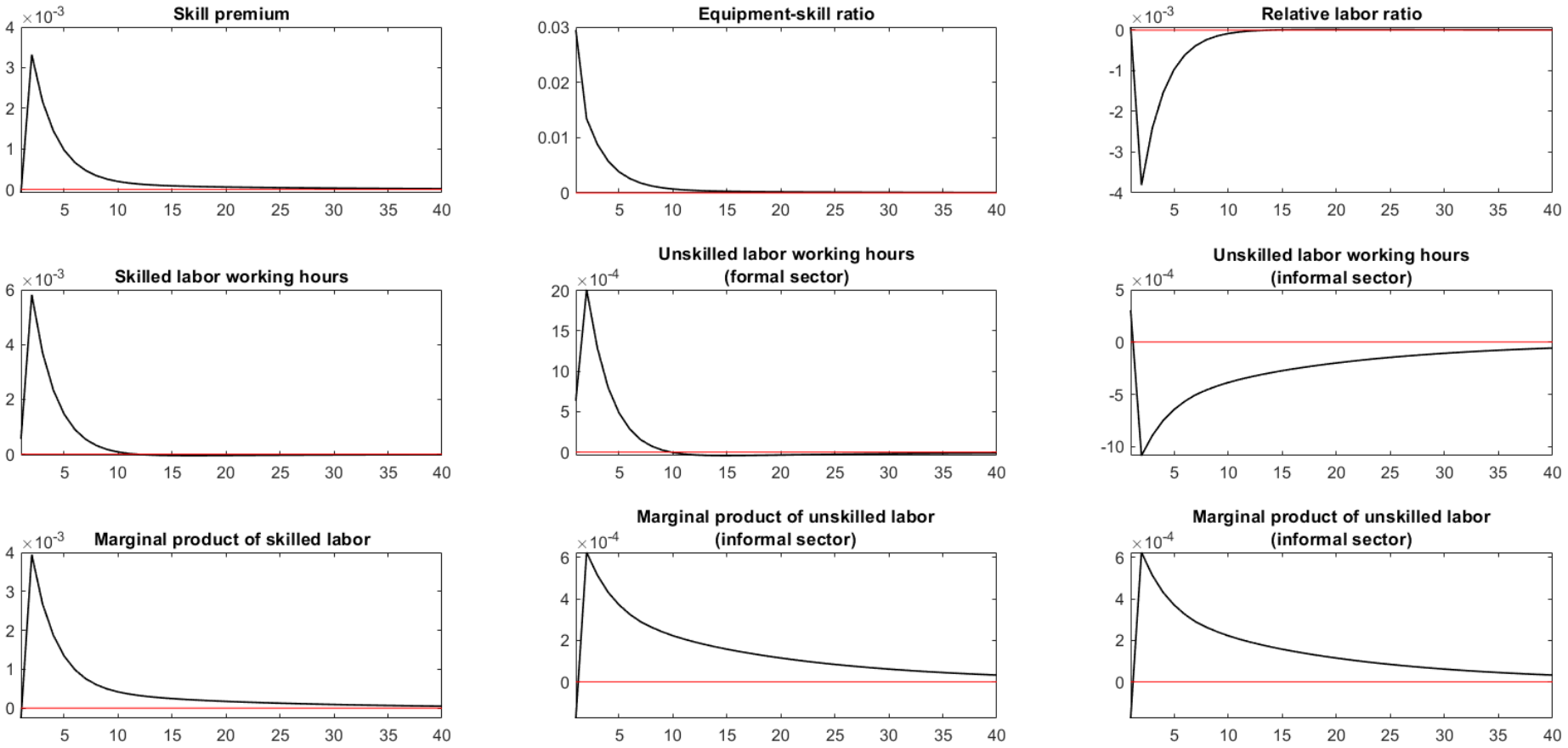

Figure 14. Impulse response functions following investment-specific productivity shock (low informal sector case)

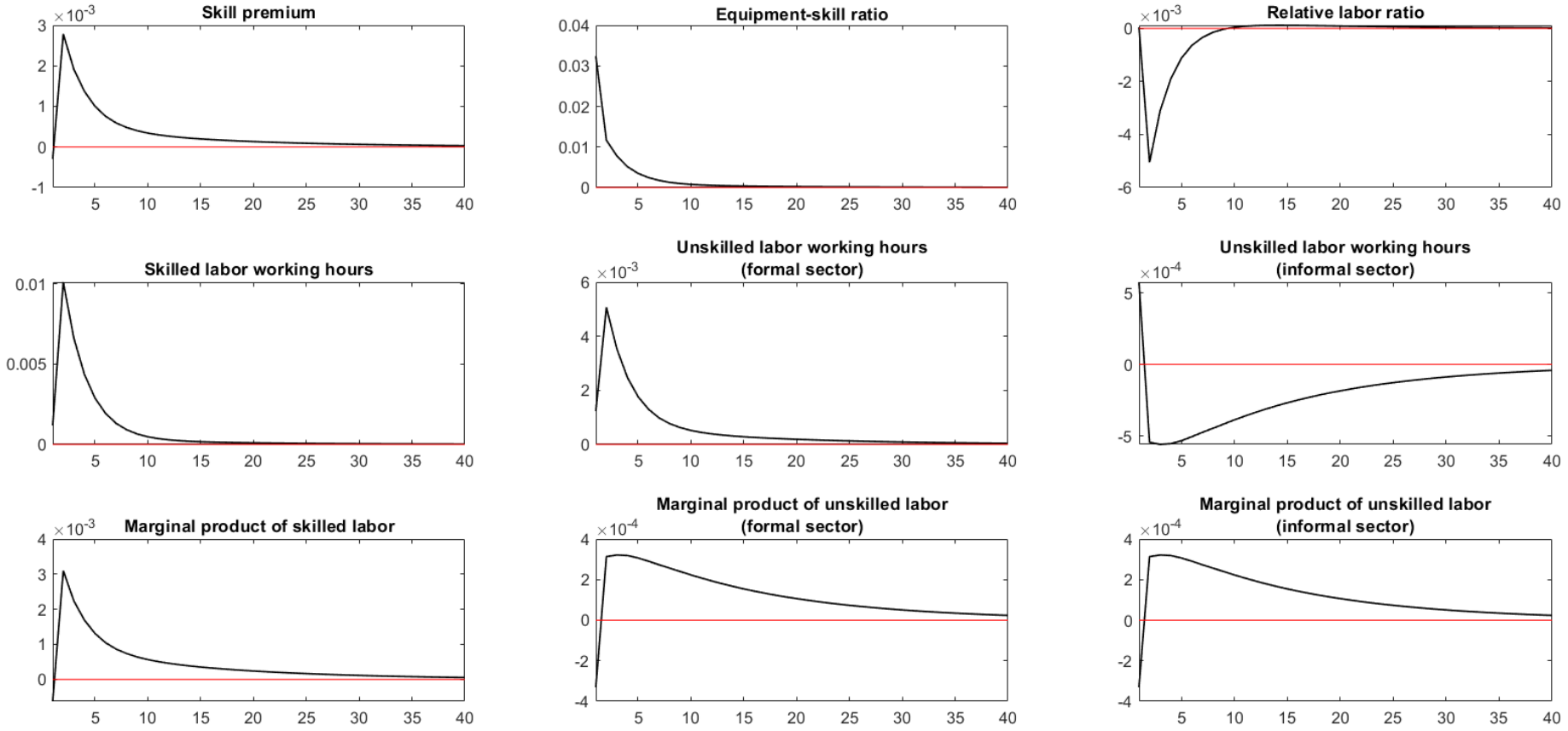

Figure 15. Impulse response functions following investment-specific productivity shock (high informal sector case)

shows slightly different response across cases, the considerably lower fall in the relative labor ratio in the economy with low informal sector size causes skill premium to increase more compared to the high informal sector case.

CHAPTER 4

SENSITIVITY ANALYSIS

In this chapter, the sensitivity of the model results to the changes in the parameter values is checked. For this purpose, different parameter values are used for the tax rate, skilled labor ratio and the degree of capital skill complementarity. For the calibration of the tax rate parameter, the ratio of total receipts from taxes and social contributions to the GDP from Eurostat database is used. The average of these ratios has been calculated for the years 2006, 2010 and 2014 for the fifteen countries, which have been chosen in Chapter 2. After that the average of the year averages has been calculated and the resulting value, 38.6%, is used as the tax ratio in the model. By using this ratio for parameter τ in the model, the relevant steady state values are calculated. The steady state values in Table 4 shows that the lower informal sector size is associated with higher skill premium, higher capital accumulation and higher output as it is found in the benchmark model.

Table 4. Steady State Results: τ=0.386

	Low Informal Sector	High Informal Sector		Low Informal Sector	High Informal Sector
k_e	0.80	0.33	w_s/w_{u_f}	1.08	0.81
k_s	1.77	0.60	k_e/h_s	1.40	1.24
k	2.57	0.99	h_{u_f}/h_s	0.71	0.34
y_f	1.35	1.10	y_i	0.18	0.36

The impulse response functions are also regenerated with τ=0.386. Figure 16 and Figure 17 show the impulse response functions following neutral productivity shock for both low and high informal sector cases. As could be observed from Figure 16 and Figure 17, changes in the skill premium and the factor input ratios follow a similar path to the benchmark case following neutral productivity shocks. The

changes in the skill premium and the equipment-skill ratio are not significantly different from the benchmark model, whereas the increase in the relative labor ratio is greater than the increase in the benchmark model for the low informal sector case. On the other hand, the increase in the skill premium is lower in the high informal sector case while equipment-skill ratio and relative labor ratio are not significantly different from the benchmark model.

Figure 18 and Figure 19 show the impulse response functions following investment-specific productivity shock when the tax rate is changed to 0.386. Although the changes in the observed variables follow a similar path with the benchmark model, there are some differences in the magnitude of the changes. The increases in the equipment-skill ratio and the skill premium are not significantly different from the benchmark case whereas the fall in the relative labor ratio is greater compared to the benchmark case for both low and high informal sector cases.

In order to control for the robustness of the model to the changes in the skilled labor ratio, the share of the population with tertiary education from Eurostat database, for 25-54 years group, has been used. The average of country ratios has been calculated, for the fifteen countries chosen in Chapter 2, and used as the parameter value for the skilled labor ratio. Table 5 shows the steady state values for the low and high informal sector cases by using the parameter value, s=0.376. As could be seen from the table, skill premium is still higher in low informal sector case. The comparative results for other variables across low and high informal sector cases are also similar to the benchmark case. The low informal sector size is associated with a higher capital accumulation, higher output, higher skill premium and higher factor input ratios.

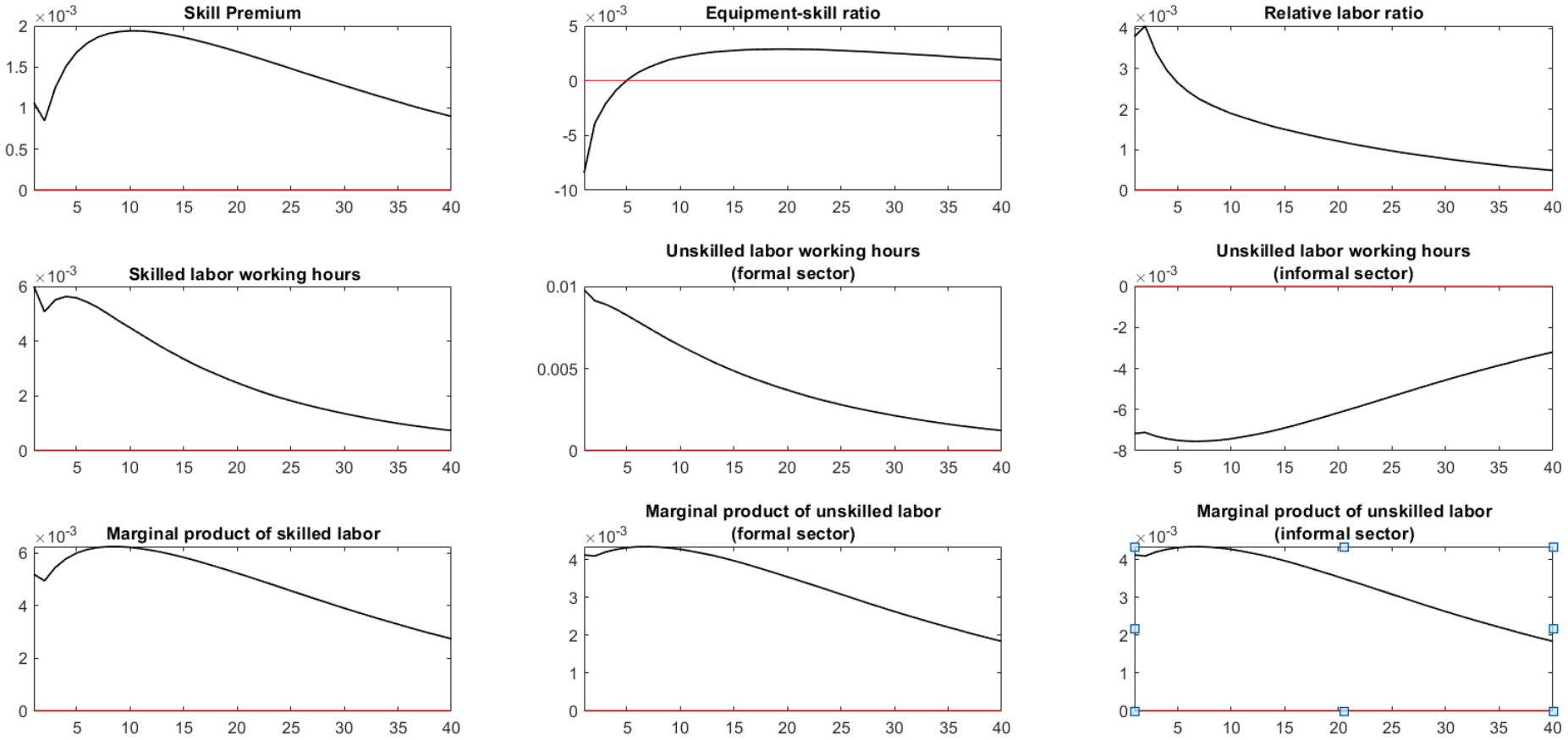

Figure 16. Impulse response functions following neutral productivity shock (low informal sector case, τ=0.386)

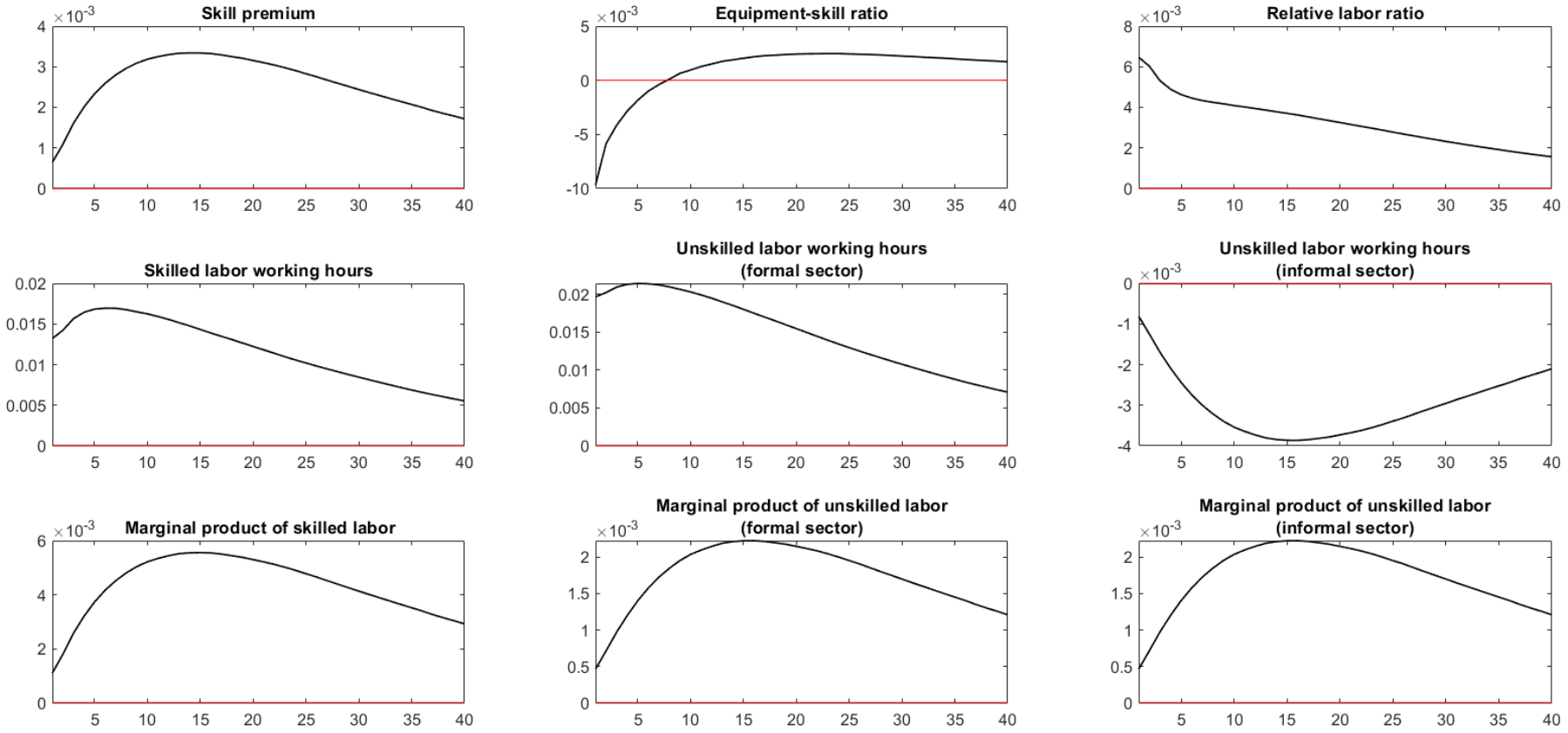

Figure 17. Impulse response functions following neutral productivity shock (high informal sector case, τ=0.386)

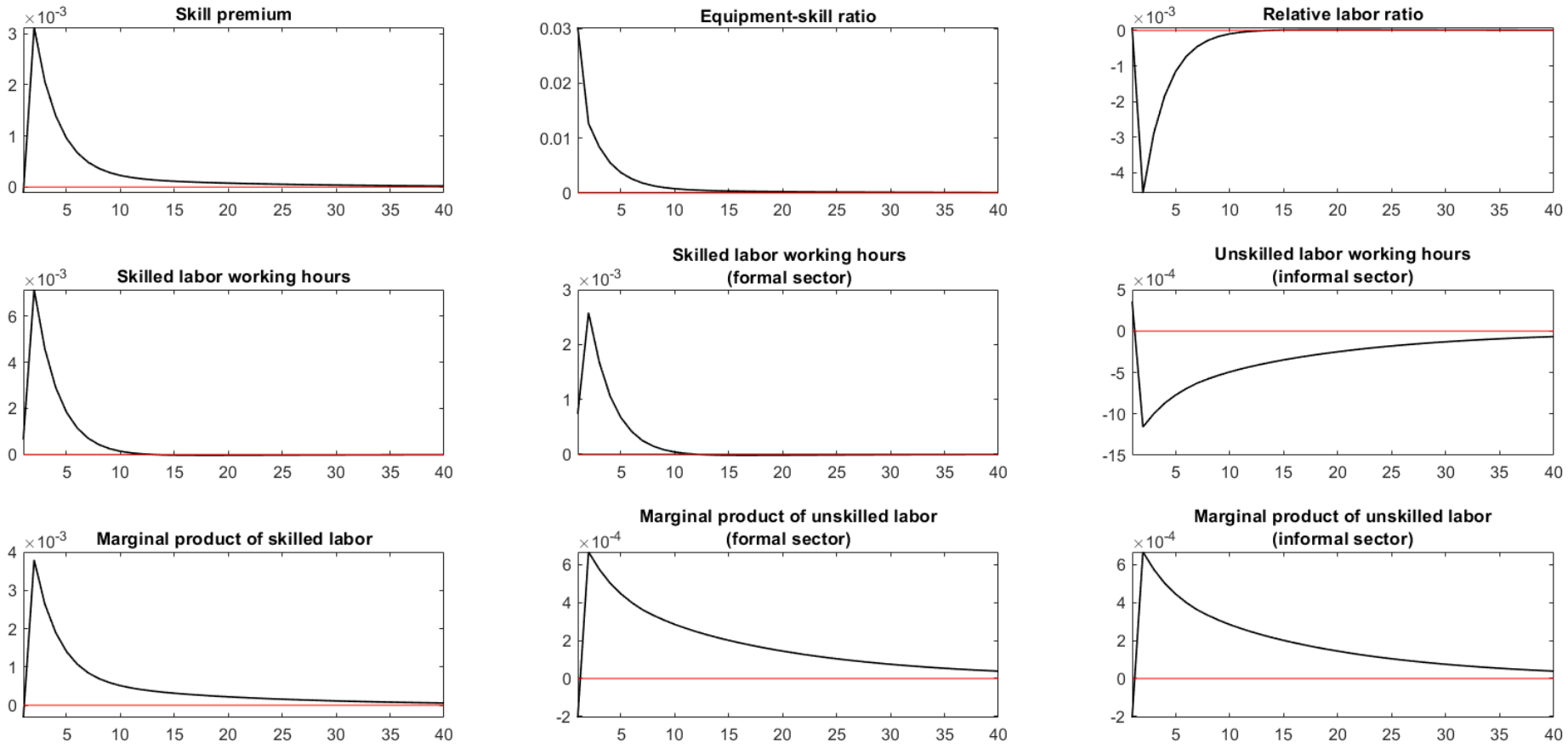

Figure 18. Impulse response functions following investment-specific productivity shock (low informal sector case, τ=0.386)

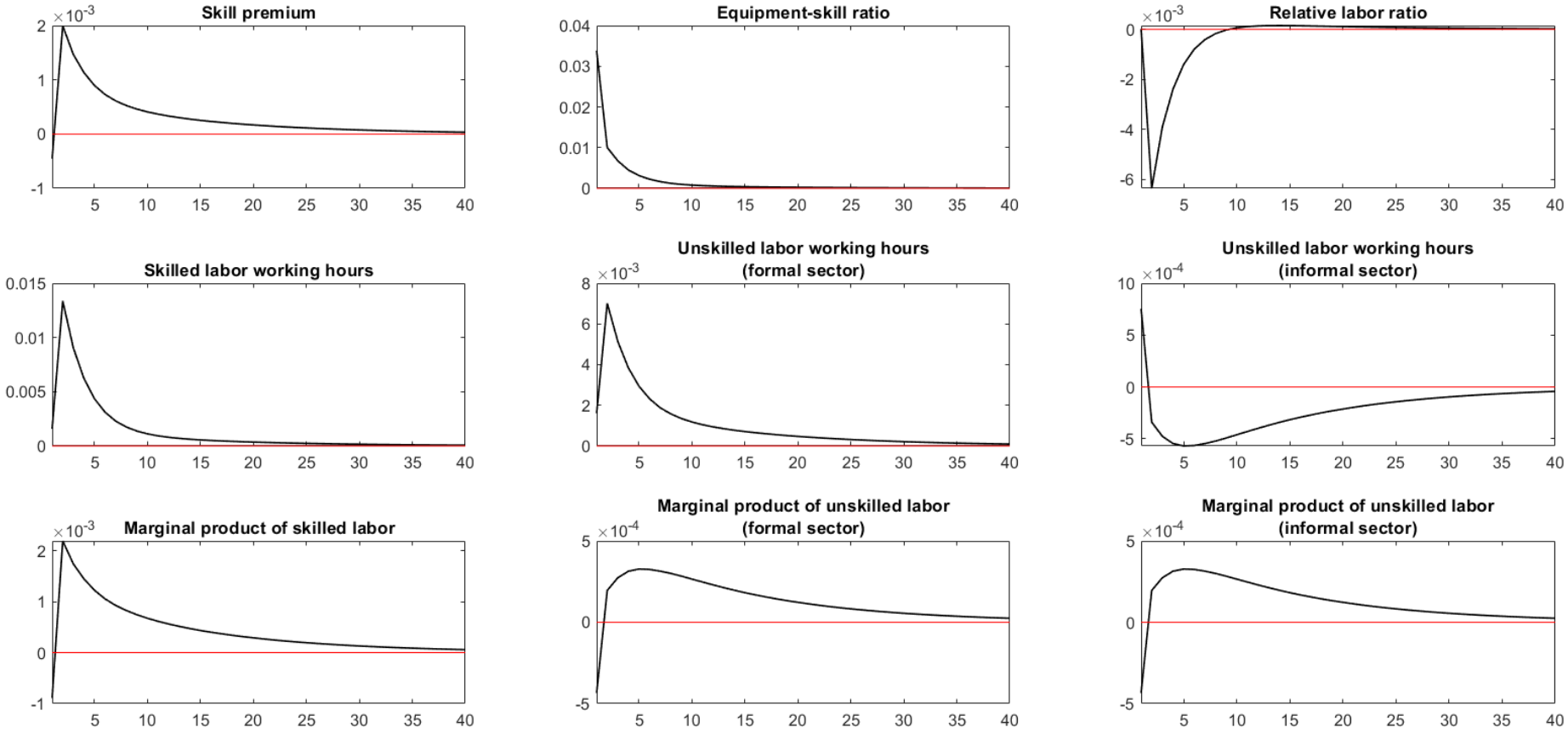

Figure 19. Impulse response functions following investment-specific productivity shock (high informal sector case, τ=0.386)

Table 5. Steady State Results: s=0.376

	Low Informal Sector	High Informal Sector		Low Informal Sector	High Informal Sector
k_e	0.782	0.277	w_s/w_{u_f}	0.818	0.566
k_s	1.185	0.333	k_e/h_s	1.281	1.109
k	1.967	0.609	h_{u_f}/h_s	0.653	0.271
y_f	1.288	1.072	y_i	0.206	0.402

Figure 20 and Figure 21 are the impulse response functions created by using the parameter value s=0.376 for the skilled labor ratio. They follow a similar path with the impulse response functions of the benchmark case with slight differences in the magnitudes of the changes. In both low and high informal sector cases, the rise in the relative labor ratio is greater compared to the benchmark model, whereas the response of the equipment-skill ratio is not significantly different from the benchmark model. On the other hand, the initial increase in the skill premium is greater than the benchmark model in the low informal sector case while the initial increase in the high informal sector case is slightly lower than the benchmark model.

Figure 22 and Figure 23 show the impulse response functions following the investment-specific productivity shock when the skilled labor ratio equals to 0.376. The fall in the relative labor ratio is lower compared to the benchmark case, when the informal sector size is low, whereas equipment-skill ratio and the skill premium are not significantly different from the benchmark model. On the other hand, the results for the high informal sector case are similar to the benchmark case for both the magnitudes and the directions of the changes.

Lastly, the parameters v and φ have also been changed, in order to check the robustness of the model results to the changes in the degree of capital-skill

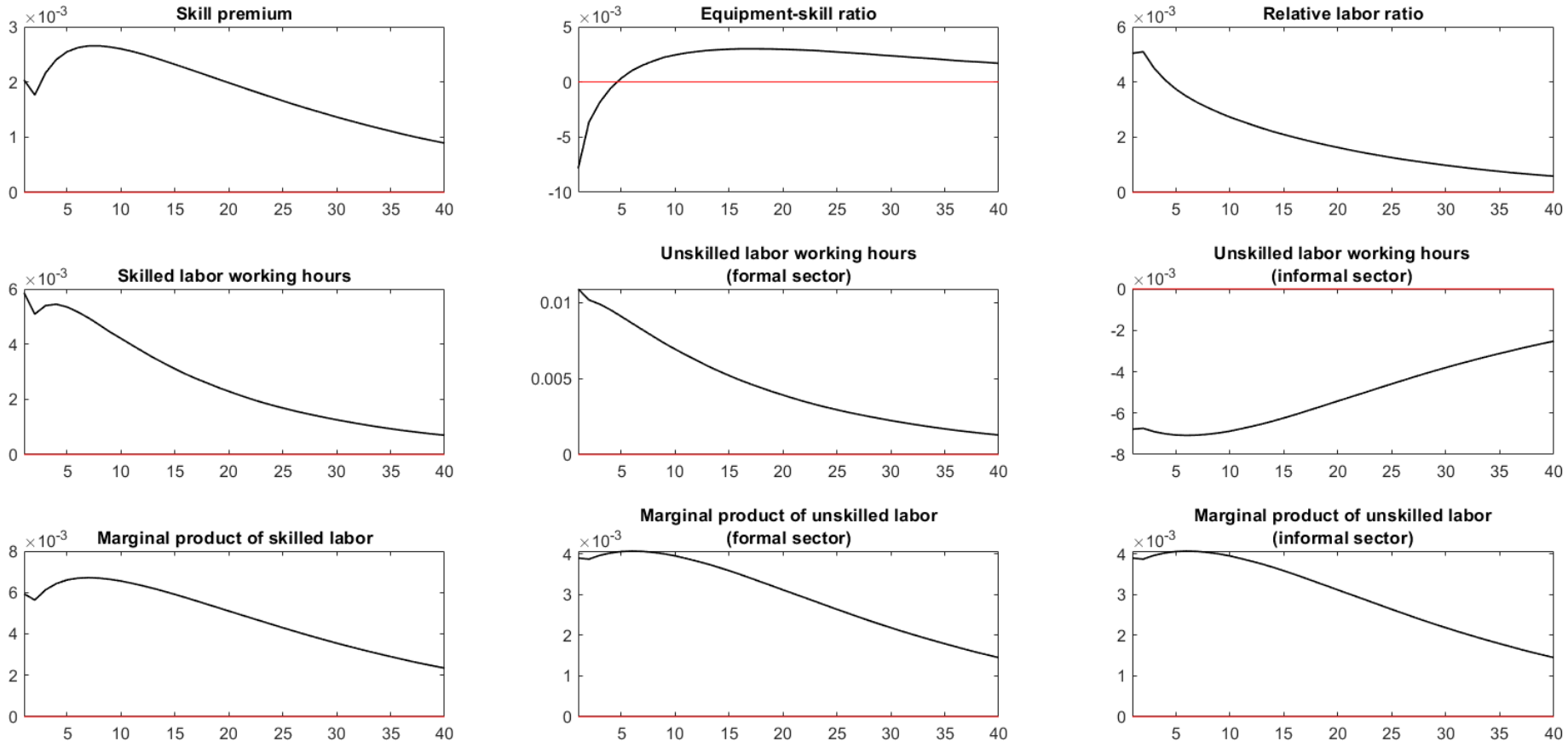

Figure 20. Impulse response functions following neutral productivity shock (low informal sector case, s=0.376)

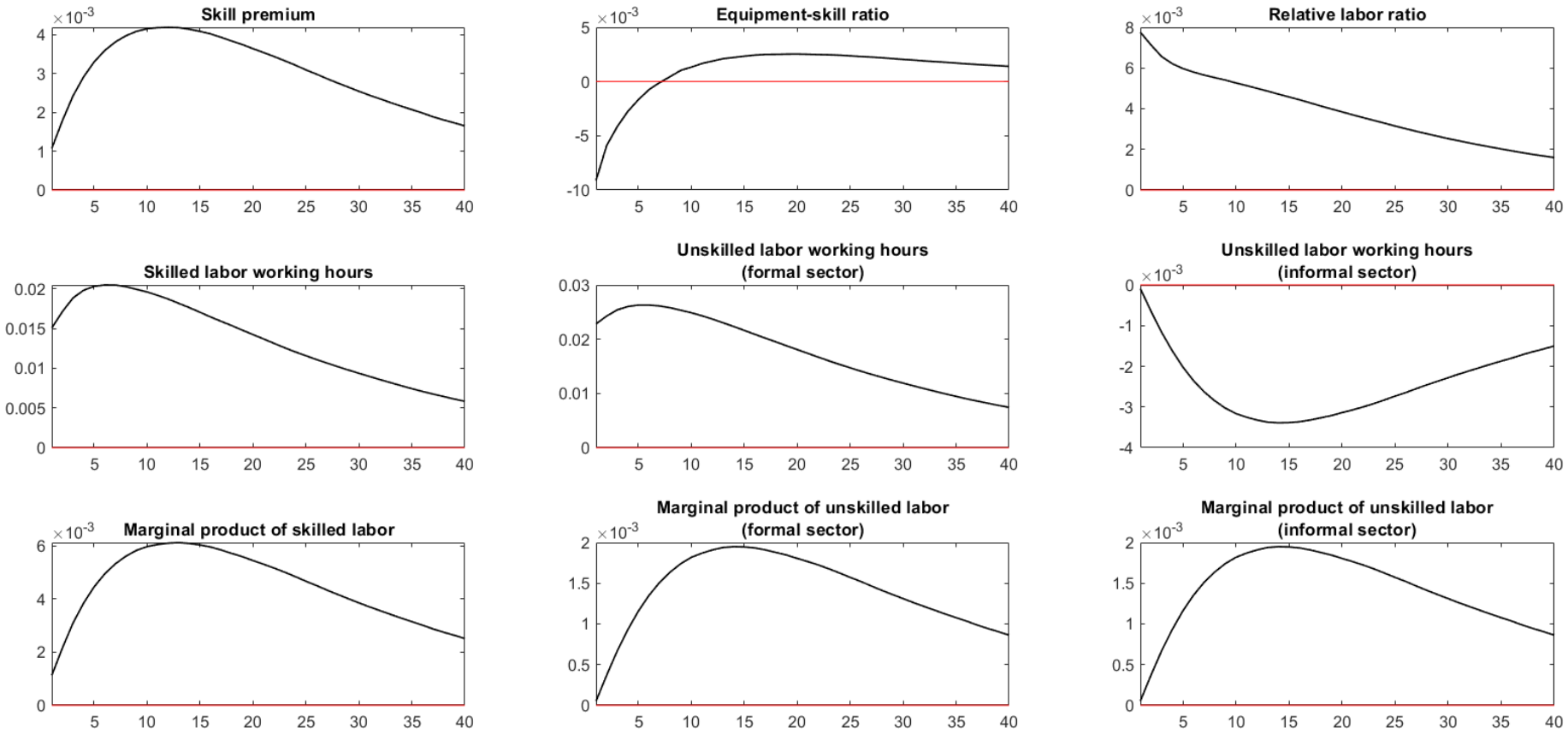

Figure 21. Impulse response functions following neutral productivity shock (high informal sector case, s=0.376)

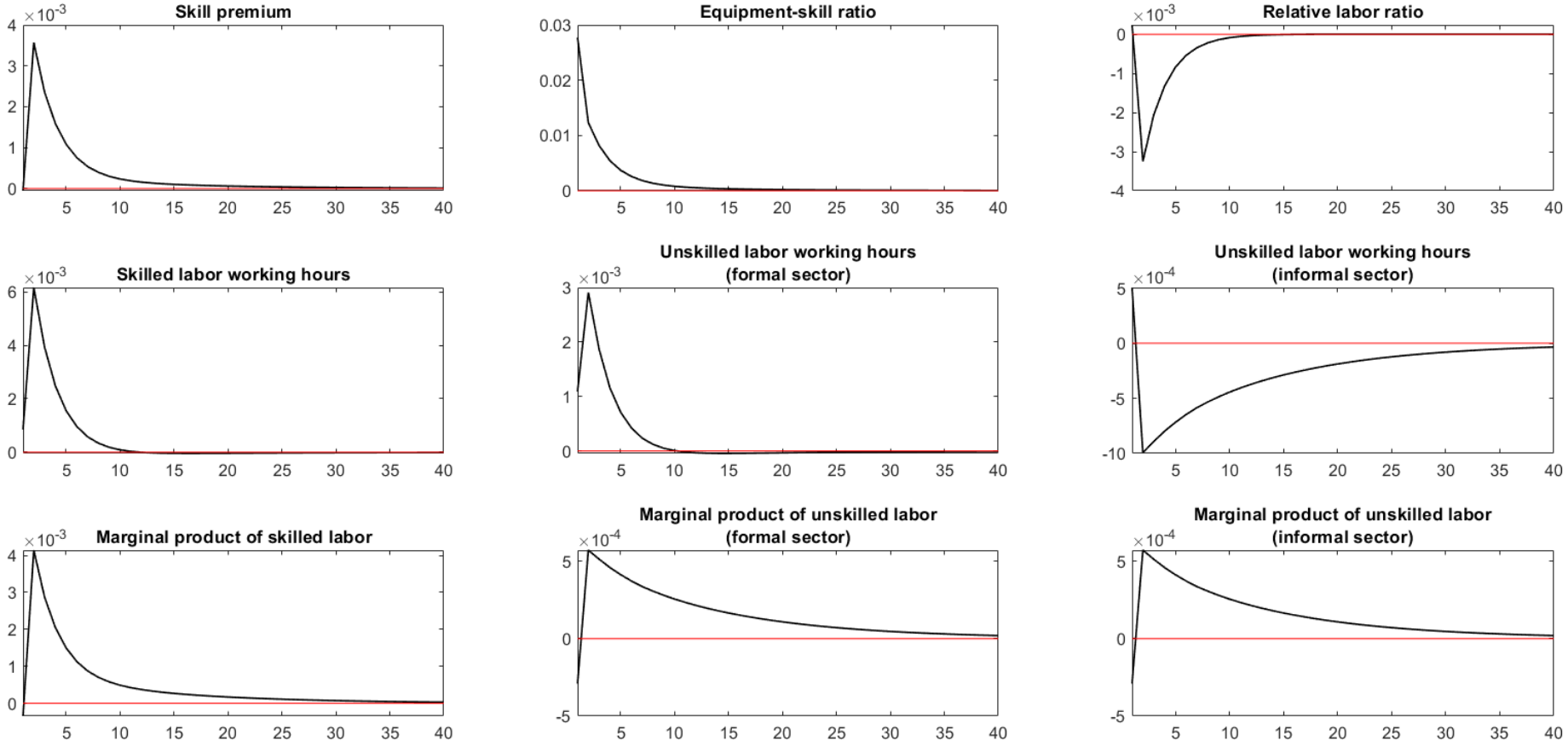

Figure 22. Impulse response functions following investment-specific productivity shock (low informal sector case, s=0.376)

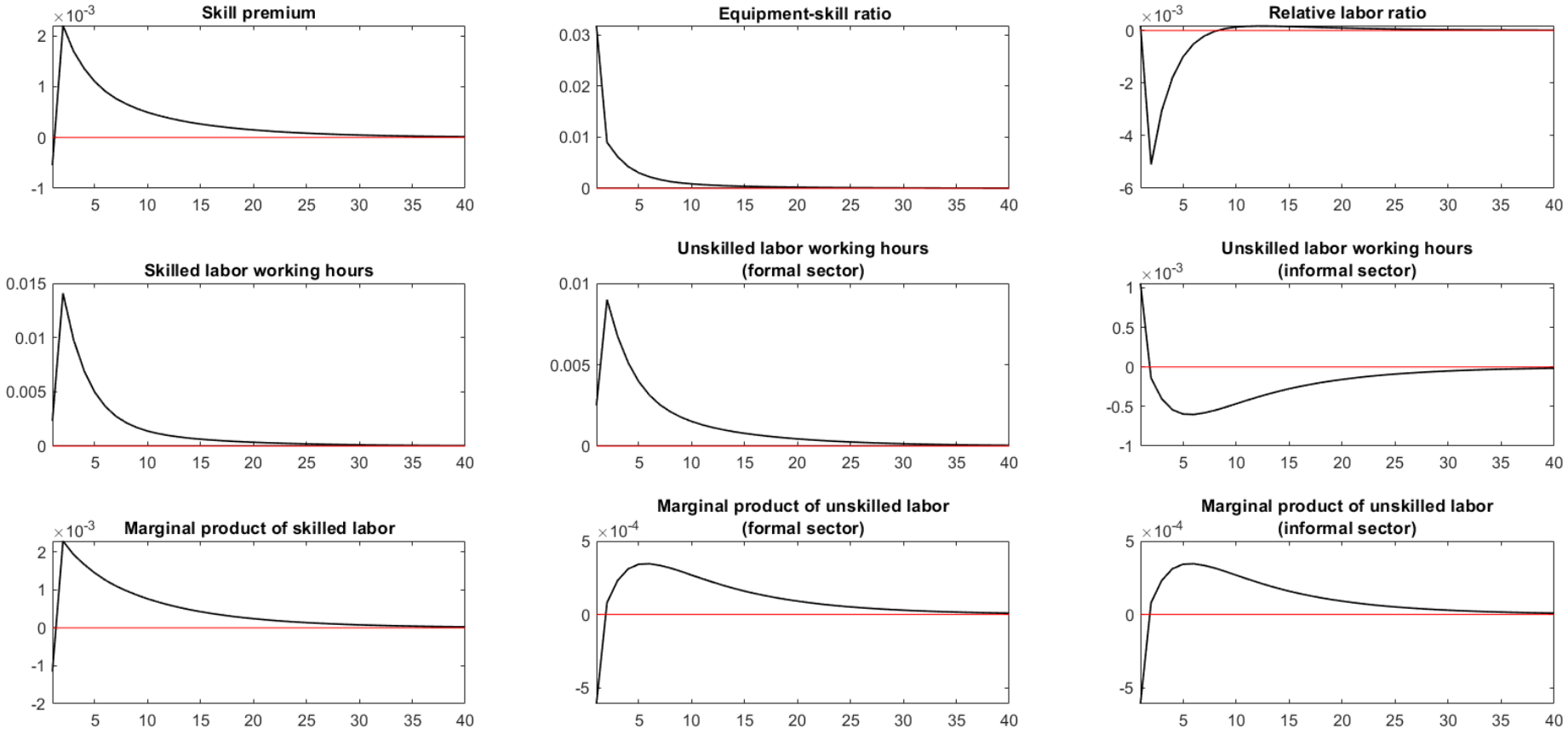

Figure 23. Impulse response functions following investment-specific productivity shock (high informal sector case, s=0.376)

complementarity. For this purpose parameters which govern the degree of capital-skill complementarity are set to the values used by Krusell et al. (2000), which are v=0.401 and φ=-0.495. The corresponding steady state values can be seen in Table 6.

Table 6. Steady State Results: v=0.401, φ=-0.495.

	Low Informal Sector	High Informal Sector		Low Informal Sector	High Informal Sector
k_e	1.592	0.834	w_s/w_{u_f}	1.157	0.894
k_s	1.655	0.725	k_e/h_s	2.376	1.994
k	3.246	1.559	h_{u_f}/h_s	0.648	0.27
y_f	1.437	1.175	y_i	0.177	0.359

It can be seen that the higher skill premium occurs in low informality case together with higher capital accumulation and higher output level. The results are similar to the benchmark case when comparing the low and high informal sector cases.

The impulse response functions following neutral productivity shock and for this level of capital-skill complementarity are shown in Figure 24 and Figure 25. They follow a similar path with the impulse response functions in the benchmark model with slight differences in the skill premium and relative labor ratio. On the other hand, Figure 26 and Figure 27 show the impulse response functions following investment-specific productivity shock. The skill premium is higher compared to the benchmark case, when informal sector size is low. When the informal sector size is high, the magnitudes of the changes in the skill premium and the factor input ratios are also close to the benchmark model The sensitivity analysis made in this chapter show that the steady state values and the impulse response functions are robust to the changes in the parameter values. The low informal sector size is associated with higher capital accumulation, higher output and higher skill premium consistent with

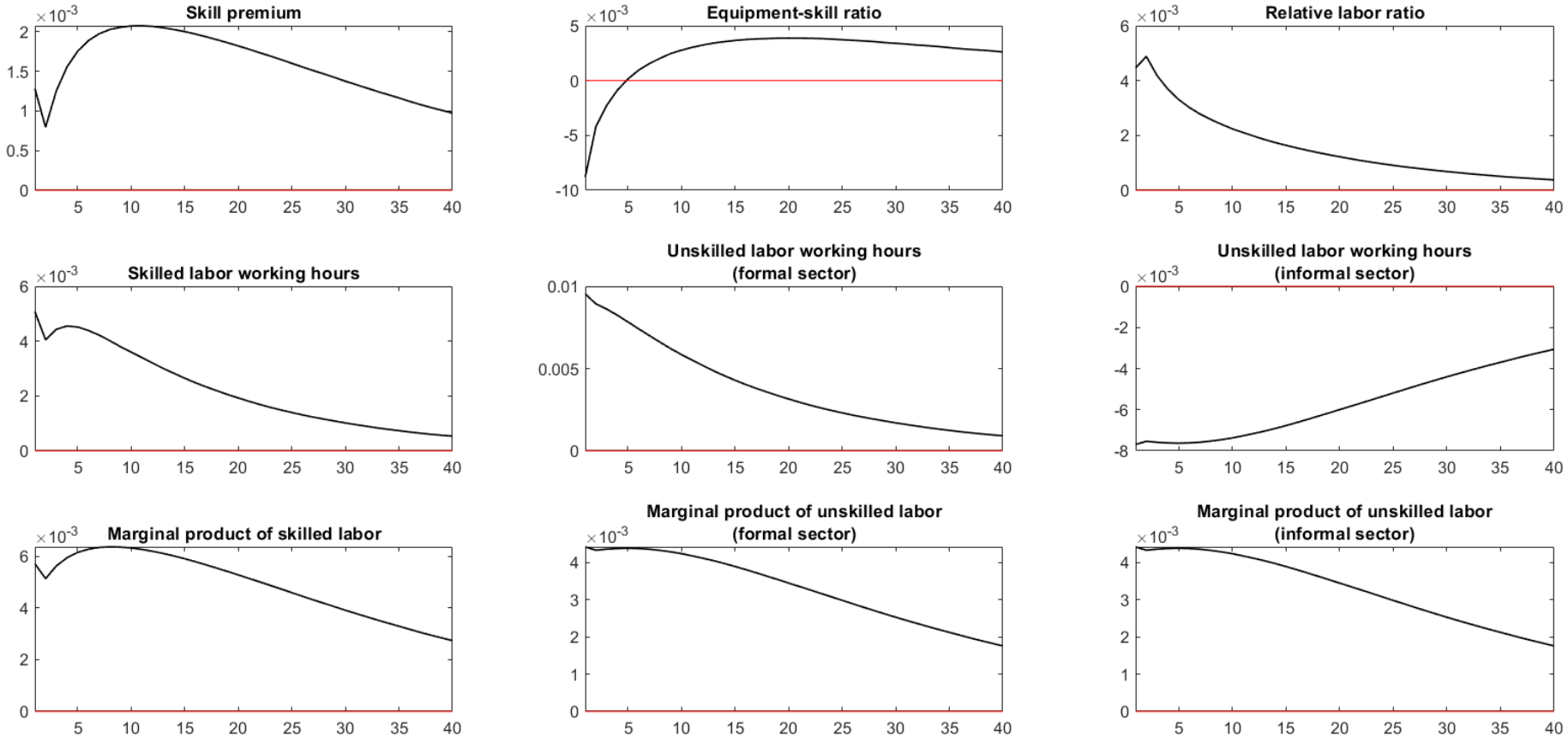

Figure 24. Impulse response functions following neutral productivity shock (low informal sector case, v=0.401 , φ=-0.495)

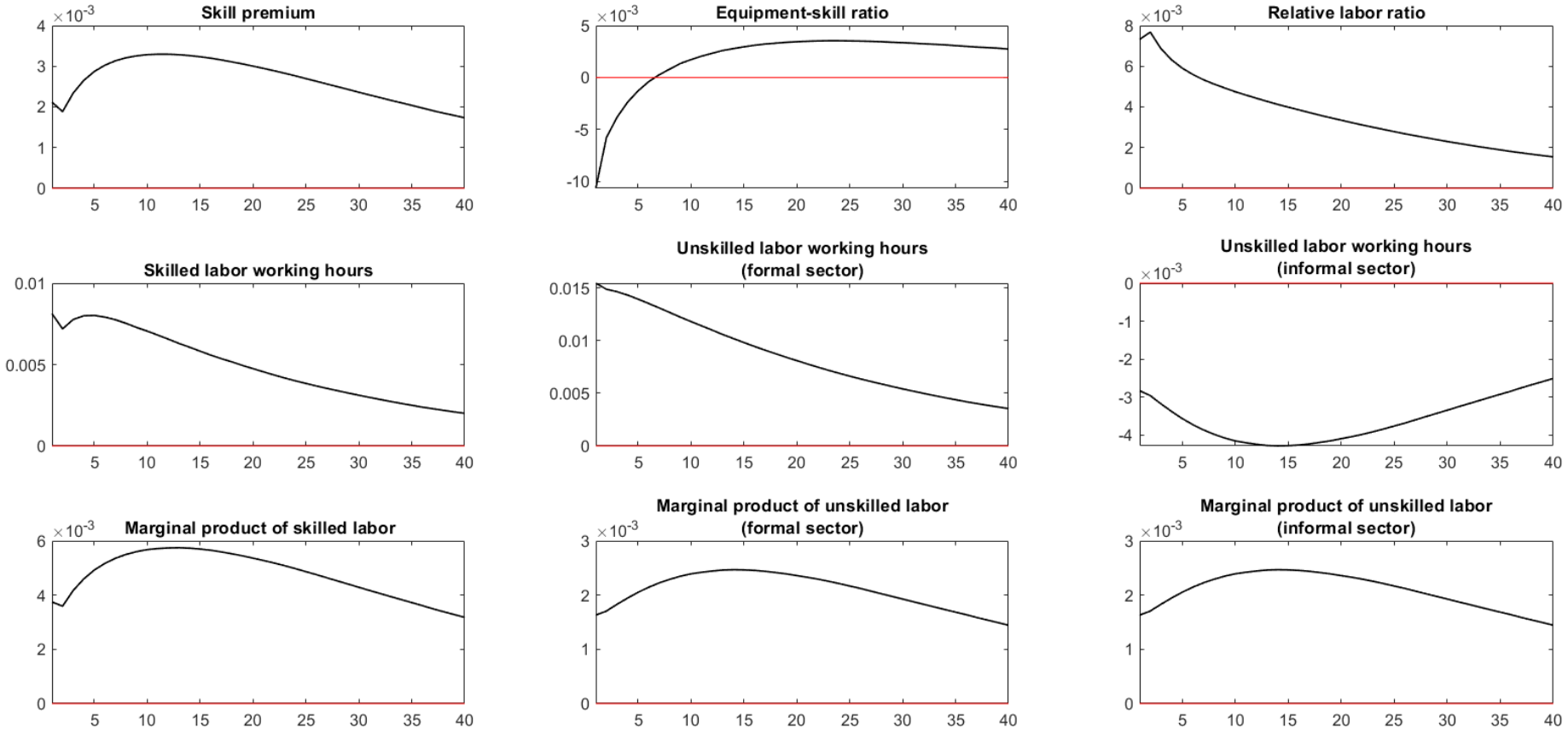

Figure 25. Impulse response functions following neutral productivity shock (high informal sector case, v=0.401 , φ=-0.495)

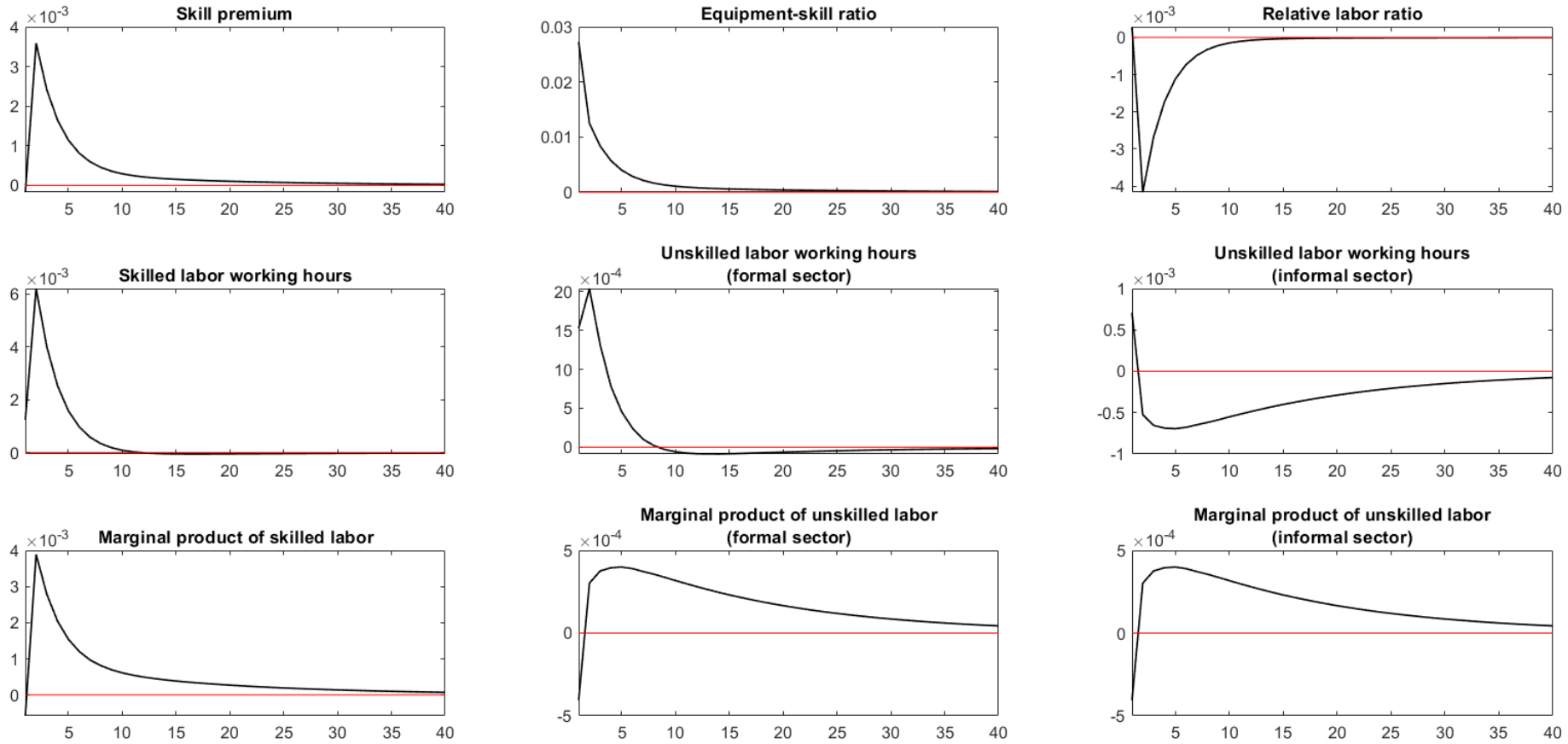

Figure 26. Impulse response functions following investment-specific productivity shock (low informal sector case, v=0.401 , φ=-0.495)

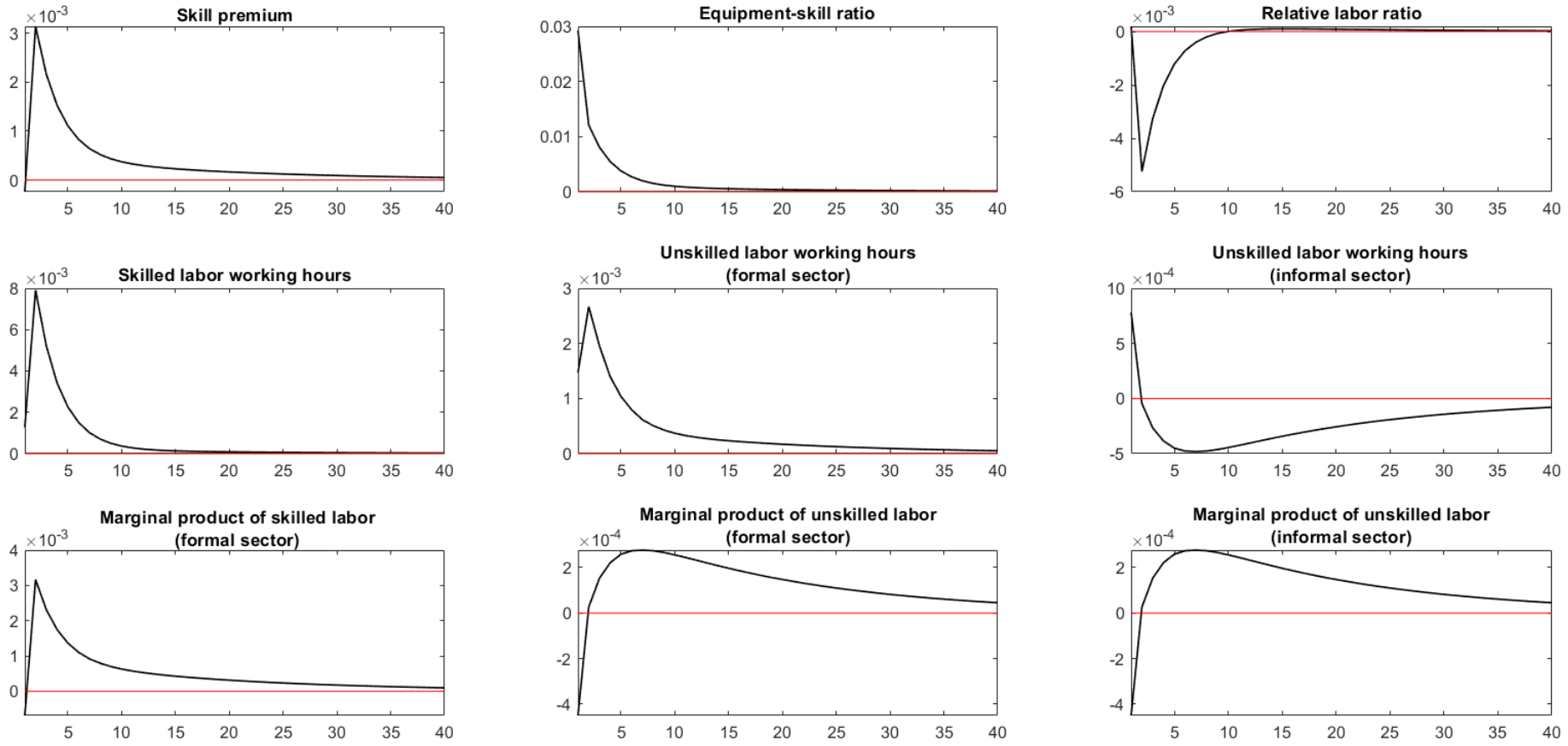

Figure 27. Impulse response functions following investment-specific productivity shock (high informal sector case, v=0.401 , φ=-0.495)

the benchmark model The impulse response functions are also similar to the impulse response functions in the benchmark model with slight differences in the magnitude of the changes.

CHAPTER 5

CONCLUSION

In this study, the relation between the informal sector size and the skill premium is observed. A regression is set up by using panel data set consisting of 15 countries and 13 years. The results from the regression show a positive relation between the skill premium and the informal sector size. A dynamic stochastic general equilibrium model is also set up in order to compare the results for the low and high informal sector size economies. By comparing the steady state values of these two cases, it is found out that the skill premium is negatively correlated with the level of the informal sector size. Although this result seems to contradict with the regression results, it might not be the case. In order to show this, steady state results for 50 different levels of informal sector size are found, and it is found out that the low informal sector size ends up with higher equipment-skill ratio, relative labor ratio, greater capital accumulation, and a greater output in the economy. If the production technology favors skilled labor more for its complementarity with the capital equipment, then the skill premium is higher because of higher marginal product of skilled labor. So, if the relation of the informal sector size to the relative labor ratio and the equipment-skill ratio is subtracted, the relation between the skill premium and the informal sector might turn out to be positive.

The same relation has been observed in a dynamic setting. It has been found out that the capital-skill complementarity, which is represented by equipment-skill ratio, causes an increase in the skill premium following both types of shocks for both high and low informal sector cases. This effect could be seen in the initial periods following investment-specific productivity shock, while it can be seen almost 10

periods after the economy is hit by a neutral productivity shock. It has been found out that the changes in the size of informal sector affect the way skill premium is affected by neutral and investment-specific productivity shocks. In the case of neutral productivity shock, informality's presence increases the relative labor ratio and hence causes a greater rise in skill premium at the initial periods despite falling equipment-skill ratio at the beginning. In the case of investment-specific productivity shock, presence of higher informal sector causes a higher fall in the relative labor ratio which eventually causes a slightly lower increase in the skill premium.

Both types of shocks cause an increase in the working hours of both types of workers in the formal sector. Correspondingly, both types of shocks cause a decrease in the working hours of the workers in the informal sector. As the marginal product of the unskilled workers in the formal sector increases, working hours of the unskilled workers in the informal sector decrease to equalize the marginal products of unskilled workers across sectors. Following neutral productivity shock, rise in the relative labor ratio is higher when the size of the informal sector is higher, because of the greater rise in unskilled labor working hours compared to the skilled labor working hours. On the other hand, investment-specific productivity shock causes a decrease in the relative labor ratio. The reason is the lower rise in unskilled labor working hours compared to the rise in skilled labor working hours as the shock affects skilled labor more than unskilled labor since it increases the marginal product of skilled labor more than it increases the marginal product of unskilled labor. Consequently, it is observed that the neutral and investment-specific shocks affect the skill premium differently for different informal sector sizes. The reason is the difference between the ways shocks affect the economy. Neutral productivity shock affects the formal sector as a whole, whereas investment-specific shock targets

skilled labor because of its skill complementarity. As a result, the neutral productivity shock causes a higher skill premium in the high informal sector case whereas investment-specific productivity shock causes a higher skill premium in the low informal sector case.

APPENDIX

FIRST ORDER CONDITIONS

1)

$$(1-\Psi)\left[{c_{u_t}}^{\alpha}\left(1-h_{u_{f_t}}-h_{u_{i_t}}\right)^{1-\alpha}\right]^{-\rho}{c_{u_t}}^{\alpha-1}(1-h_{u_{f_t}}-h_{u_{i_t}})^{1-\alpha}$$

$$=\Psi\left[{c_{s_t}}^{\alpha}\left(1-h_{s_t}\right)^{1-\alpha}\right]^{-\rho}{c_{s_t}}^{\alpha-1}(1-h_{s_t})^{1-\alpha}$$

2)

$$\frac{(1-\Psi)\mathrm{u}\left[{c_{u_t}}^{\alpha}\left(1-h_{u_{f_t}}-h_{u_{i_t}}\right)^{1-\alpha}\right]^{-\rho}{c_{u_t}}^{\alpha}(1-h_{u_{f_t}}-h_{u_{i_t}})^{-\alpha}}{G_{h_{u_{f_t}}}(K_{s_t},K_{e_t},H_{s_t},H_{u_{f_t}})}$$

$$=\frac{\Psi\mathrm{s}\left[{c_{s_t}}^{\alpha}\left(1-h_{s_t}\right)^{1-\alpha}\right]^{-\rho}{c_{s_t}}^{\alpha}(1-h_{s_t})^{-\alpha}}{G_{h_{s_t}}(K_{s_t},K_{e_t},H_{s_t},H_{u_{f_t}})}$$

3)

$$(1-\tau)G_{K_{s_{t+1}}}\left(K_{s_t},K_{e_t},H_{s_t},H_{u_{f_t}}\right)+1-\delta_s$$

$$=e^{q_t}\left[(1-\tau)G_{K_{e_{t+1}}}\left(K_{s_t},K_{e_t},H_{s_t},H_{u_{f_t}}\right)+\frac{1-\delta_e}{e^{q_{t+1}}}\right]$$

4)

$$\frac{\left[{c_{s_t}}^{\alpha}\left(1-h_{s_t}\right)^{1-\alpha}\right]^{-\rho}{c_{s_t}}^{\alpha-1}(1-h_{s_t})^{1-\alpha}}{\left[{c_{s_{t+1}}}^{\alpha}\left(1-h_{s_{t+1}}\right)^{1-\alpha}\right]^{-\rho}{c_{s_{t+1}}}^{\alpha-1}(1-h_{s_{t+1}})^{1-\alpha}}$$

$$=\beta\left[e^{z_{t+1}}(1-\tau)G_{K_{s_{t+1}}}\left(K_{s_t},K_{e_t},H_{s_t},H_{u_{f_t}}\right)+1-\delta_s\right]$$

5)

$$(1-\tau)G_{h_{s_t}}\left(K_{s_t}, K_{e_t}, H_{s_t}, H_{u_{f_t}}\right) = \frac{sc_{s_t}(1-\alpha)}{(1-h_{s_t})\alpha}$$

6)

$$(1-\tau)G_{h_{u_{f_t}}}\left(K_{s_t}, K_{e_t}, H_{s_t}, H_{u_{f_t}}\right) = F_{h_{u_{i_t}}}\left(H_{u_{i_t}}\right)$$

where marginal products of production factors are as follows:

$$G_{h_{u_{f_t}}}\left(K_{s_t}, K_{e_t}, H_{s_t}, H_{u_{f_t}}\right) = e^{z_t}K_{s_t}^{\theta}\frac{1-\theta}{v}\left[\mu H_{u_{f_t}}^{v} + (1-\mu)(\lambda K_{e_t}^{\varphi} + (1-\lambda)H_{s_t}^{\varphi})^{v/\varphi}\right]^{1-\theta-v/v}\mu v u_f^{v} h_{u_{f_t}}^{v-1}$$

$$G_{h_{s_t}}\left(K_{s_t}, K_{e_t}, H_{s_t}, H_{u_{f_t}}\right) =$$

$$e^{z_t}K_{s_t}^{\theta}\frac{1-\theta}{v}\left[\mu H_{u_{f_t}}^{v} + (1-\mu)(\lambda K_{e_t}^{\varphi} + (1-\lambda)H_{s_t}^{\varphi})^{v/\varphi}\right]^{1-\theta-v/v}(1-\mu)\frac{v}{\varphi}(\lambda K_{e_t}^{\varphi} + (1-\lambda)H_{s_t}^{\varphi})^{v-\varphi/\varphi}(1-\lambda)\varphi s^{\varphi} h_{s_t}^{\varphi-1}$$

$$G_{K_{s_{t+1}}}\left(K_{s_{t+1}}, K_{e_{t+1}}, H_{s_{t+1}}, H_{u_{f_{t+1}}}\right) = e^{z_{t+1}}\theta K_{s_{t+1}}^{\theta-1}\left[\mu H_{u_{f_{t+1}}}^{v} + (1-\mu)(\lambda K_{e_{t+1}}^{\varphi} + (1-\lambda)H_{s_{t+1}}^{\varphi})^{v/\varphi}\right]^{1-\theta/v}$$

$$G_{K_{e_{t+1}}}\left(K_{s_{t+1}}, K_{e_{t+1}}, H_{s_{t+1}}, H_{u_{f_{t+1}}}\right) = e^{z_{t+1}}K_{s_{t+1}}^{\theta}\frac{1-\theta}{v}\left[\mu H_{u_{f_{t+1}}}^{v} + (1-\mu)(\lambda K_{e_{t+1}}^{\varphi} + (1-\lambda)H_{s_{t+1}}^{\varphi})^{v/\varphi}\right]^{1-\theta-v/v}(1-\mu)\frac{v}{\varphi}(\lambda K_{e_{t+1}}^{\varphi} + (1-\lambda)H_{s_{t+1}}^{\varphi})^{v-\varphi/\varphi}\lambda\varphi K_{e_{t+1}}^{\varphi-1}$$

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