Macroeconomic Policy effects on development transition – Views from Agent based model

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Abstract

Assessing the impact of a policy before implementation has often been a difficult feat to achieve, both at the macroeconomic and microeconomic levels. This challenge becomes even more daunting in the context of a developing country and has encouraged enormous amount of research over an extended period of time using different models. Traditional models for assessing the impact of policy implementation are fragmented given the assumption that factors affecting such policies are homogeneous whilst neglecting the interactions between various markets. Agent-based modelling can overcome this limitation given its capability to provide a micro-founded macroeconomic analysis of policy, within a variety of economic conditions and policy objectives to facilitate the understanding of the observed response. Against this backdrop, the current work adopts an agent based framework to investigate three distinct policies that have been employed by some advanced countries towards achieving sustainable development goals. This is carried out to derive lessons and explore opportunities for enhancing policy implementation in developing countries. Agent representation involve decisions by involve manufacturers, households (final goods consumers), banks (loan issues & bankruptcy

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warning), central bank (Basel monitor & monetary policy activity), government (fiscal policy role) and singular energy market supplier, which enables consideration of: the impact of unemployment benefits on the labour market; the impact of capital investment subsidy on investment levels; and the impact of energy taxes (in the form of an increase in the energy cost structure) on a developing country's macroeconomic system. Results shows that an increase in unemployment benefits led to improvements in the labour market and reduction in wage margin, with a limitation threshold of 50%. Additionally, it was observed that the economy becomes more sensitive to energy tax due to higher unemployment benefits, although the diminishing nature of the relationship was quite noticeable.

Keywords: Development policies; Incentives & unemployment benefit; Investment incentives; Production efficiency; Development economy; Agent based model

1 Introduction

In the past few years, the United Nation (UN) came up with 17 goals to transform the world under the auspices of key sustainable development goals (SDGs) with the view to end poverty, protect the planet and ensure prosperity for all [1]. While some developing countries have recorded resounding success in attempts to achieve the SDGs, more have lagged behind in this endeavour. A number of reasons have been identified with the key factor being the overall global economic slowdown in the region. In some of the developing countries and other developed countries in the West that have excelled during this period, a few policies have been identified as integral to achieving the SDGs. The key questions therefore are: (i) how would similar policies be harnessed in the context of development transition, especially in Africa? (ii) How would a policy such as increases in the unemployment benefits impact the economic system of a developing country? (iii) Given that many developing countries are already struggling with insufficient public funds, would the benefits of such a policy outweigh the costs? (iv) How would an investment subsidy policy, which subsidizes the cost of investment in the best technology in any given industry impact on economic outcomes? (v) Will such policies bring a typical developing country closer to achieving the SDGs, or would it constitute a disadvantage to an already fragile economy? Providing answers to the highlighted questions through the lens of agent based modelling is the focus of this work.

Many theoretical and empirical macroeconomic studies have been undertaken with the view to provide viable answers to such questions. In fact, it can be argued that, given the current data availability, some of these questions have already been answered to an extent and their empirical analysis thereof have been well exhausted. However, most of empirical analysis provided in the extant literature have adopted traditional models for assessing the viability of some of the questions highlighted. Such approaches are fragmented given the assumption that the underlying factors considered are homogeneous in nature

whilst neglecting the interactions between various factors. The use of agent based modelling (ABM) technique have been empirically verified to possess the capability to address such limitations [2-4], due to its ability to generate events of heterogeneous activities based on embedded decision rules and learning process using bottom up approaches [5, 6]. Another competitive edge that the use of ABM offers lies in its ability to integrate phenomena such as cognitive science, evolutionary economics and computer science in a systematic fashion for addressing real life problems [7]. A popular version of a comprehensive macroeconomic ABM is the Eurace@Unibi, which is often parametrised to replicate empirical settings of a macro economy with the view to evaluate the efficacy of any given policy [8]. The modus operandi of the Eurace is to explain socio-economic phenomena through the construction of artificial societies with the view to generate explanations and observe trickle effects from the bottom upwards [9]. In essence, it simulates crucial connections in the real economy and many other facets of the macroeconomy owing to micro specifications and rules [10]. The ABM is therefore an alternative approach aimed at achieving a more wholesome and comprehensive representation of the economy without having to deal with the data limitations that often plague empirical analysis. As such, it can be adopted to understand the modern economy better and, more importantly, to assess many of the policy strategies, which are often blindly followed, before they are implemented.

In light of the above, the current work extends and adapt an existing agent based source code for two purposes: (1) to promote the standard application of an agent-based framework; and (2) to evaluate hypothetical policy sensitivity with respect to efforts geared towards attaining SDGs in the context of developing countries. An extension of the Eurace@Unibi open source fits this purpose owing to its market size coverage and model features such as multinomial choice by households and the Leontief production function. Additionally, a great deal of time is saved on the modelling of new framework given the provisions for well-grounded, free codes for policy evaluation.

Through the adoption of the existing ABM model, the current work exploits the simulation performance of low profit tax rates at 10% and 20% before proceeding with further scenarios. This adaptation for a developing transition is reflected through low profit tax for attracting investors and varying unemployment benefit rates, while providing an industrious computational avenue for experiments with policy initiatives, shocks and other pertinent issues important for a developing economy in as far as sustainable development is concerned. The ability to simulate a realistic economic environment without the problems caused by limited data availability makes an ABM analysis of potential policy designs a significant addition to the macroeconomic literature.

From a macroeconomics perspective, the focus of this study is to explore a few of the policy designs that are often adopted in order to push developing countries towards attaining the stated SDGs. In this regard we focus our analysis on the impact of unemployment insurance in the form of unemployment

benefits. In essence we use the adapted ABM to assess how changes in the magnitude of unemployment benefits, ranging from 10% to 50% of previous income, interplay with different macroeconomic outcomes in the embedded economic environment. This question has been explored in studies that analyse labour market policies, although their ability to explore the interplays which this paper explores, has been limited [11-14]. The general consensus in the literature is that unemployment benefits, while great for welfare, can be detrimental to the labour market owing to the negative incentives generated. However, there are studies which have found a positive relation between unemployment benefits and post-employment earnings and duration [11]. This paper will therefore expand on the overall impact of an often promoted labour market policy.

The paper also considers the often proposed capital investment subsidy [15, 16] and its interplay with the labour market, policy sensitivity in the economy and investment levels. This subsidy is designed specifically to target investors that invest in the best technology in that specific industry. The idea is that it creates an environment where firms have an incentive to invest in the best technology in order to obtain the said subsidy and this would in turn lead to gains from improved technology assimilation in the economy. The general consensus in the literature supports this finding. Empirical results point to an increased investment activity and better outcomes when some investment subsidy exists. However, the opposite occurs when unfavourable conditions are attached to such subsidies [17-20]. In these scenarios, ABM analysis can uncover both the impact on the investment outcomes in the economy and the indirect impact on other aspects of the economy. In such a scenario, the possible negative impact of this policy design can be envisaged and duly accounted for.

Finally, the study assesses changes in energy tax as a cost component of the production function of firms in the economy, and examine how such changes interplay with other aspects of the economy. From a theoretical perspective, we anticipate an increase in energy tax (this tax assumes that energy prices will rise in the future and will drive the switch to renewable energy), which will lead to an increase in costs and a reduction in output in the system. However, given the goal of such a tax does not necessarily lead to an immediate increase in renewable energy usage or an immediate decrease in costs, but rather to a reduction in energy consumption over the long term. We experience the impact of such a change over two decades after the energy tax has been implemented.

To summarise, the cardinal aim of the current work is to explore comprehensively some of the other interplays of policy initiatives that are often untestable in empirical analysis, which has to focus on a single dependent variable at a time. Against this backdrop, the current work therefore investigates the following:

i.) The impact of unemployment benefits on the labour market in a developing country

ii.) The impact of investment (best capital technology) subsidy (i.e., producers are only subsidised when they invest in the best technology in the industry)

iii.) The impact of an energy tax (in the form of an increase in the energy price–cost structure) on system.

In the light of the above, the remainder of the paper is structured as follows. In section 2, a brief review on unemployment benefits, capital relevance to manufacturing and performance, and policies for enhancing development. The review presented in section 2 forms the lens through which the current work is viewed. The methodology extension underpinning the adopted agent-based model is provided in Section 3. In section 4, the findings of the results are presented and discussed as well as highlighting the implications of the research on policy effectiveness leading to summary and concluding remarks in Section 5.

2 Literature review

Several studies have been undertaken into the relevance of social security policies in developing countries. For example, Ginneken [21] examined the role of social security coverage, adjustment and poverty globally, showing that developing countries lagged behind significantly with this programme and several other social policies. The article was written over a decade ago, but not much has changed in the implementation of social benefit frameworks in several African countries. Wibbels and Ahlquist [22] studied development, trade and social insurance in developing countries. Arguing that governments' choice of development strategies is conditioned by the size of the domestic market, the relative abundance of labour and land inequality in a closed international trading system, they suggested that economic policies in the 1950s, 1960s and 1970s had important implications for the emergence and current contours of social policy in the developing world.

Economic growth and improving living standards have benefited several regions of the world since the industrial revolution, but Africa is portrayed as exception owing to several factors. According to findings by Oketch [23], Africa needs both human and physical capital investments to attain industrial development, as the sources of labour productivity growth in the medium term in African nations are high investments in physical and human capital. Evidence of capital structure and firm performance have been investigated with theoretical and empirical data supporting this notion. See for example [24] on the case of Nigeria, and [25] on Kenya. As such, our adapted ABM echoes that human and physical capital investments are required to improve economic productivity and stimulate industrial development.

Attaining these industrial developments at a faster pace requires effective and stable government interventions. In addition to social benefits for unemployment, investment and job creation must be stimulated. This requires effective government interventions in developing economies, for example subsidy interventions. Input subsidy programmes in the agricultural sector are on the increase in some African countries south of the Sahara. These programmes have proven to be successful in aiding poverty reduction and diminishing price shocks [26]. The input subsidy programmes are a favoured policy tool of many African governments in partnership with international institutes.

Questions arise about subsidy programmes in the manufacturing sector. The high presence of large foreign-owned manufacturers poses challenges. However, subsidy incentives in the South Africa's film and television sector, for example, led to social and labour market transformation in the sector. The objectives of the subsidies (job creation, and the transfer of skills and knowledge) were attained [27]. Although South Africa may be considered to be an emerging economy, it plays an intermediary role for evaluating this policy effectiveness. Based on a review comparison between South Africa, Malaysia and Singapore, and the promotion of investment in the manufacturing industries of these countries, Wentzel and Steyn [28] suggested that incentive introduction or modification should be considered in South Africa. They could also apply to investment in capital assets, capital allowances for equipment used to produce renewable energy, incentives for research and development, and several other identified areas. An incentive subsidy example for South Africa is towards development of the auto industry, which has aided development of new techniques and technologies. See for example [29] on reviews of economics of the South African motor industry, and [30]on manufacturing performance and policy in South Africa.

Beg *et al*. (2002)[31] noted that, although economic growth and poverty reduction are the main priorities of policy-makers in developing countries, climate change mitigation provide opportunities that can lead indirectly to the improved integration of environment and development issues such as income distribution. Theoretically, unemployment benefits can be framed as the beneficial redistribution of gains in public wealth due to improved development and growth. The social benefit is also viewed as a means of poverty and crime reduction. Public admiration of government relevance and support through benefits from tax payments are used as political subjects for incentive votes for a working government and a system that empowers the poor [32]. On the other hand, studies have criticized effects on unemployment benefits to the labour market. For instance, Nickell[33] associated presence of high unemployment with an indefinite condition of generous unemployment benefits, high overall taxes and union wage bargaining. Lack of pressure and willingness to obtain work were also cited as contributing factor towards unemployment, which also vary to differences in social insurance programs. With this view, the study restricts benefit threshold to 50%, and in view of affordability structure for a developing economy.

If a policy is developed to stimulate investment, its benefits should include job creation, skilling the population through research development and employee skills demand, innovation, technology diffusion, production growth, sales and higher tax revenue for government owing to increased employment and production. To structure a non-biased investment subsidy system, policy-makers must devise system administration processes, and take into account the time and implementation costs of searching for and identifying the best investments and firms to subsidise. Competition and firm size may hamper subsidy access for small firms and or new start-ups. Government may subsidise investments that firms would have made without access to subsidies [34], other than challenge of higher subsidy rate costs to sustain during economic downturns, while subsidy payments are not guaranteed to the achieve goals of the policy.

2.1 The role of agent based modelling for testing the efficacy of policy initiatives

As highlighted earlier, a number of definitions exist for ABM in the literature but based on practical applications, it can simply be described as a decentralised approach to model design where the active entities (i.e. the agents) which can be individuals, companies, assets, communities are identified by the modeller. The behaviours (i.e. main drivers, memory) of these active entities are then defined and put into a certain environment where connections between all defined parameters can be established. Traditional models for assessing the impact of policy implementation abound but their underlying framework are fragmented given the assumption that factors affecting such policies are homogeneous whilst neglecting the interactions between various factors. Agent-based modelling can overcome this limitation given its capability to provide a micro-founded macroeconomic analysis of policy, within a variety of economic conditions and policy objectives to facilitate the understanding of the observed response. Accordingly, a number of researchers have adopted ABM framework to test the efficacy of policy initiatives.

For instance, in their work Snape, Boait [4] employed ABM to ascertain whether domestic consumers in the UK will adopt the renewable heat incentive (RHI) introduced by the UK government to encourage the use of renewable energy generation technologies such as heat pumps. They provided a detailed analysis of different barriers, notably non-financial barriers, to the uptake of such incentives and concluded that there is a tipping point beyond which the adoption of the RHI is likely to decline very sharply due to the complex and stringent compliance requirements for RHI. Their results based on ABM was able to highlight other factors that was missed by the policy makers as to the slow rate adoption of RHI in the UK.

Similarly, Malleson, Heppenstall [35] adopted ABM to gain a deeper understanding of processes behind crime with the view to improve upon existing policies towards the development of crime prevention

strategies that are efficient and effective. Their work allows for both human and environmental factors to be simulated based on ABM. Additionally, Bloomquist [36] carried out a comparison of ABM to ascertain how they can be tailored to inform policy decisions regarding the evasion of income tax. Their work emphasised the importance of validity for models with the view to represent phenomena in the real world which policy makers may find useful and interesting. ABM has been used in informing decisions in land use science [37]; land use and land cover change [38]; regional land-use research [39] ecological economics [40, 41]; seasonal climate forecast applications among smallholder farmers [42]; and a host of other areas too numerous to be mentioned.

However, in the context of employing ABM towards testing the efficacy of policy initiatives in developing countries especially in Africa, there is opportunity for intensifying research work in this area. This constitute a major challenge that must be addressed given the rate at which policy initiatives are created in Africa without adequate information on the efficacy of such policies in instances where they are implemented. Against this backdrop, this work seeks to address this gap in knowledge by adopting a robust ABM model to test the efficacy of a policy initiative. In the section that follows, a brief description of the overall methodological framework is presented.

3 Methodology – Sustainable development transition

Stern [43] debated the benefits of developing an integrated, transdisciplinary science of human-energy interactions towards enhancing roles of energy consumers and energy producers in influencing further development and regulation decisions. In the model extension, a single energy supply market is integrated for determining average energy prices to meet the constant energy demands of manufacturers. Energy consumption and cost are only considered for manufacturers that sustain additional production input, such as transport and electricity costs. Equation 1 shows energy price updates with constant mark-up $\eta = 0.1$ and change in demand from last two periods (t-2, t-1) ΔED. For regulation and market shock sensitivity using the same simulation environment, Equation 2 depicts the price increase structure with energy tax levy ($\mathcal{T}_t^e$ tax rate). These factor in consumers' response to energy price change with economic development. According to Fouquet [44], the level of economic developments varies with energy consumption service. For example, at low levels of economic development, energy service consumption tends to be quite responsive to per capita income changes; at mid-levels, consumption tends to be very responsive to changes in income per capita; and, at high levels, consumption is less responsive to income changes. This inference the importance of formulating integrated energy service policies to reduce risks to developing countries of locking in to carbon intensive infrastructure or behaviour. A raw material supplier agent is integrated in a simplistic manner to adjust for raw material input demand. The manufacturer is a price taker of an exogenously given price determined with a constant monthly mark-up described by Equation 3.

$$p_t^E = [1+\eta][1+\Delta ED]p_{t-1}^E \quad (1)$$

$$p_t^{E,\mathcal{T}_t^e} = [1+\mathcal{T}_t^e]p_t^E \quad (2)$$

$$p_t^M = [1+\eta]p_{t-1}^M \quad (3)$$

With the notion that without guidance and incentives, rapid economic development is likely to lock consumers into high energy service prices in the long run and bind the economy onto a high energy intensity trajectory with major long-run economic and environmental impacts (Fouquet, 2016). Producer incentives are another approach to contributing to technological change and economic development, and therefore also to material waste reduction and production efficiency due to input–output ratios.

To account for production incentives, a manufacturer's production cost (ρ_t) comprises energy cost ($p_t^{E,\mathcal{T}_t^e} q_E$), raw material cost ($p_t^M q_M$), labour cost ($p_t^L q_L$) and capital cost ($p_t^C q_C^x - S_t^{C,V} p_t^C q_C^V$). This is summed by Equation 4, where p_t^M is material price, p_t^L labour price and p_t^C capital price; and q_E is quantity of energy, q_M is material quantity, q_L is employee quantity and q_C^x capital. $S_t^{C,V}$ is subsidy rate. With output Y_t based on a Leontief function, production technology τ is resource efficiency of a manufacturer's capital stock and average employee skills at time T. Production technology is manufacturer specific and advances according to new developments in capital investments and employee skills. To qualify for a capital subsidy, a manufacturer agent has to take delivery of capital goods above a certain level ($\geq V$) in the system, classified as criteria for a best technology threshold.

Overtime capital stock of vintages is subject to depreciation, as depicted by Equation 5. As manufacturers require capital loan to embark on new capital investments, governance of capital finance becomes vital through the credit market in order to minimize system run effects from producer bankruptcy. The credit market design logic is of interest as several African economies are already implementing or planning to implement a Basel II bank capital requirement system [45]. The bank agent follows a Basel II framework making the model a good fit to integrate credit market role in sourcing production capital loans, which further aids development, amid challenges facing banking system in Africa. A finding by Nyantakyi and Munemo [46] on Ghana, Tanzania and Kenya firm data suggests that increasing policy access to better capital goods will spur technology gains from positive productivity in the African manufacturing sector.

To note, the investment criteria and capacity is in reference to vintage level which indirectly portrays employee skills level and demand by the manufacturer. Labour cost is due to employee wages matched with number of wage offers and skills in the system. Employees make up the subset of household agents and as such wage is ranked according to matching mean wage offer and skills, or mean wage owing to

number of employees ($\bar{w}/q_L$). Wage offer is updated with Equation 6. The model accounts for the redistribution of wealth, with total income estimated as summation of unemployment benefit, dividend payment and bond interest income. Unemployment payment is calculated as percentage of last labour income and may trigger an economic burden during economic downswings at higher rates. For unemployment brackets to balance in the system, the labour market and employment rate strike out. At lower unemployment rates, unemployment benefits are deemed less burdensome to the government at both low and high unemployment benefit rates. At higher unemployment rates, the unemployment benefit rate is critical for weighing on government budget.

Both energy and raw materials are dependent on production level derived from labour and the capital input technology process. Proportional levels of production input to output are described by Equation 7, where α and β are coefficients of production levels. Energy demand is then driven by resource efficiency of manufacturer investment decisions. The higher the investments, and depending on capital vintage levels, the higher production costs borne, which transmit to efficiency of input cost savings and subsidy gains, creating a triple-win scenario for the government, manufacturer and the environment. These stimulate investment, job creation and waste reduction from production efficiency. On the other hand, a failed policy outcome may not reflect in the subsidy cost burden on government, while households may also bear the costs of higher final goods prices and/or inventories of unsold goods by manufacturers.

$$\rho_t = \sum p_t^C q_C^x - S_t^{C,V} p_t^C q_C^V + p_t^L q_L + p_t^{E,\mathcal{T}_t^e} q_E + p_t^M q_M \quad (4)$$

$$K_t = (1-\delta) K_{t-1}^x + \Delta I_t^x \quad (5)$$

$$W_t^{skill} = W_{t-1}^{skill}(1 + w_t^{skill}); \qquad if\ vacancy > min(vacancy) \quad (6)$$

$$E_t^{demand^i} = \frac{\alpha Y_t^{prod}}{\tau}; M_t^{demand^i} = \frac{\beta Y_t^{prod}}{\tau} \quad (7)$$

Output price follows a general pricing rule of production cost divided by total production quantity, and a constant mark up of 20%. Production is delivered to a distribution centre where households are randomly matched and ranked weekly, according to a multinomial logit process. Sales amounts are then recorded according to inventory levels at the distribution centre. Profit is revenue from sales less production cost. Profit tax is levied when > 0. For government agents, revenue is composed of tax revenue, bond finance and dividends, while expenses include manufacturer subsidy, bond purchase, interest payment and investment expenditures. When an existing model is applied, this section avoids repeating equations that can be found in [10, 47]. This study observes system performance, production investment incentives and unemployment benefit policies, with scenarios in Table 1. The assumption is that a growing economy is associated with a growing energy demand, therefore investment support through best capital purchase subsidies may improve production efficiency and job creation. The

challenge is to evaluate policy sustainability. Bazilian *et al*. [48] reviewed various challenges concerning governments' role in promoting energy security, managing climate change and ensuring environmental sustainability in Sub-Saharan Africa. A need for increased focus on interrelated aspects of energy governance and policy to induce investment and alleviate poverty was identified.

Table 1: The study provides simulation scenarios that compare the following:

	Scenario 1	**Scenario 2**
*Case Policy incentives	Corporate profit tax 10%, 20%; Subsidy 0%, 5%, 10%, 15%; Unemployment benefit rate 10%, 20%, 30%, 40%, 50%; *C1; We compare two corporate profit tax rates as factors that influence producer investment behaviour and the sourcing of government revenue.	Corporate profit tax 10% Subsidy 0%, 5%, 10%, 15%; Unemployment benefit rate 10%, 20%, 30%, 40%, 50%; Energy Tax 2.5%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, 20%; *C2.

4 Results

Trends in output, energy consumption, wages, investment levels and unemployment rates over a period of 20 years are presented. These may contribute to questions about sustainability of policy actions in several developing countries with low or non-standard unemployment benefit structures. The agent population includes one capital goods supplier, 80 firms, one central distributor, 1 800 households, 20 financial services providers, one government, one central bank, one clearing centre, one energy supply market, and one raw materials supply market. Results are provided figuratively. Figures 1 to 4 depict selected trends sequentially over 20 years, while figures 5 to 9 depict average values for the same 20-year period. Results show that in an atypical developing country economy, performance varies in response to different policy rates. For example, in Figure 1, a 20% profit tax in tandem with a 10% best capital investment subsidy indicates the highest return on tax revenue.

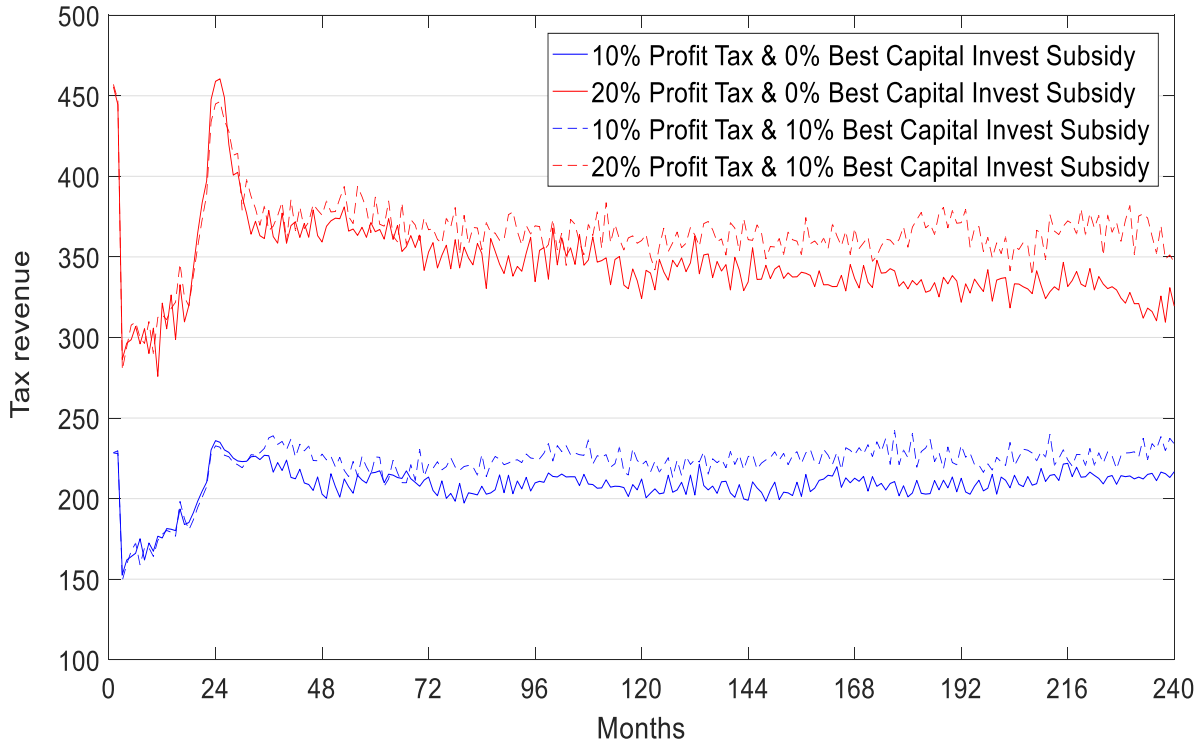

Figure 1: Confirmation of tax revenue benefits in simulation trial at 50% Unemployment benefit rate

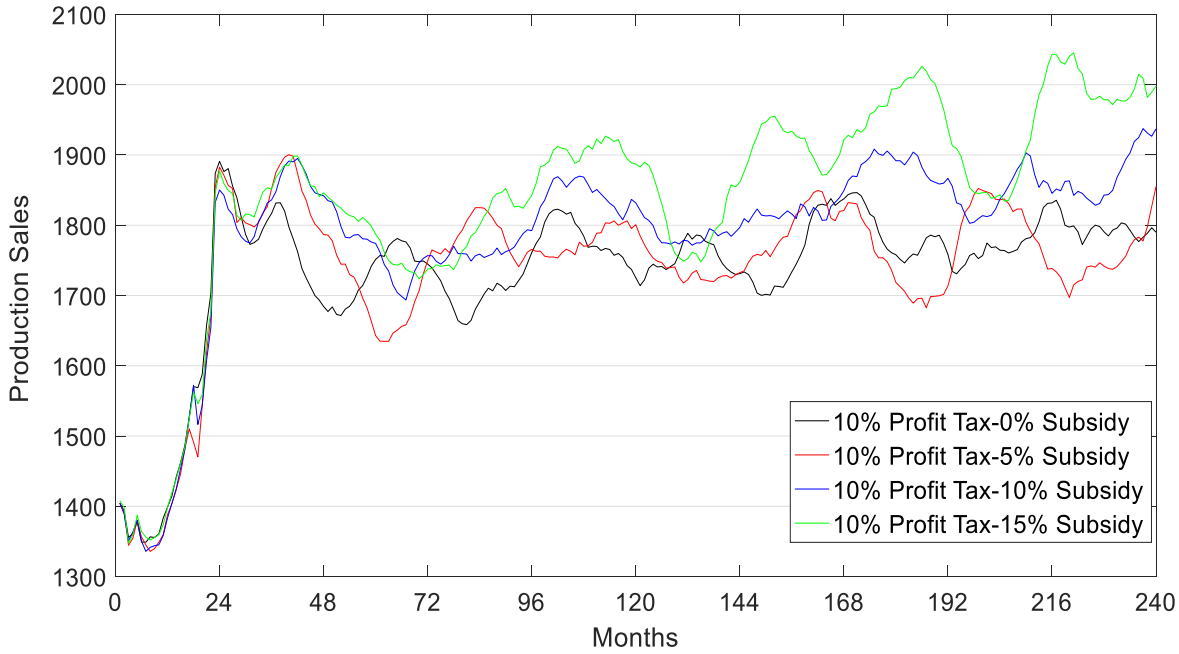

Figure 2: Confirmation of production sales benefits in simulation trial at 50% Unemployment benefit rate

In a similar manner in Figures 2 to 4, we again see a positive impact of a 10% profit tax and above 10% investment subsidy on production sales, although when we consider both unemployment and good prices, we see a significant increase in both as a result of such a policy. Bearing in mind that, all the policies tested in Figures 1 to 4 are coupled with a 50% unemployment benefit, and the effects of these policies traced over the next 20 years in the economy. In the first two cases, there is an initial drop in

both tax revenue and production sales, however as the economy adjusts, the benefits of such a policy begin to manifest in the system. In the two other cases in Figures 3 and 4 however, the initial impact is a sharp rise in both goods prices and unemployment, and then a gradual fall. The economy does not really recover to its pre-policy levels however. This implies that caution must be exercised when it comes implementing such policies within a developing economy setting. Reasons for such reactions in the system could be due to the affordability structure. In subsequent analysis, we vary the unemployment benefit rate from 50% to 30%, and this does not seem to improve the impact of profit tax and investment subsidy on unemployment in the long-run (See Figures c & d, in the appendix). Observations suggests unemployment benefit seems initially unsustainable in long term without investment stimulating subsidy as tax revenue falls over the 20 years trend. This is also reflected in the gross domestic product (GDP) recorded (figure a2, in the appendix), although not on a downward steep as tax revenue (figure a1, in the appendix). This is not the same with 50% UB, as improvements in tax revenue (figure a3, in the appendix) and GDP (figure a4, in the appendix) are observed. This could imply gains from improved production and sales as reflected in Figure 2, which is supported by Nicholson and Needels'[49] theory that unemployment insurance aids consumption power for employees out of work. A notable limitation of our simulation is lack of consideration of differing unemployment benefit according to unemployment rate in the system, which has been challenged theoretically and empirically to influence consumption trade off and job search behaviour according to business cycles [50]. Nonetheless, subsidies play complementary role to shocking unemployment benefit cost to the system.

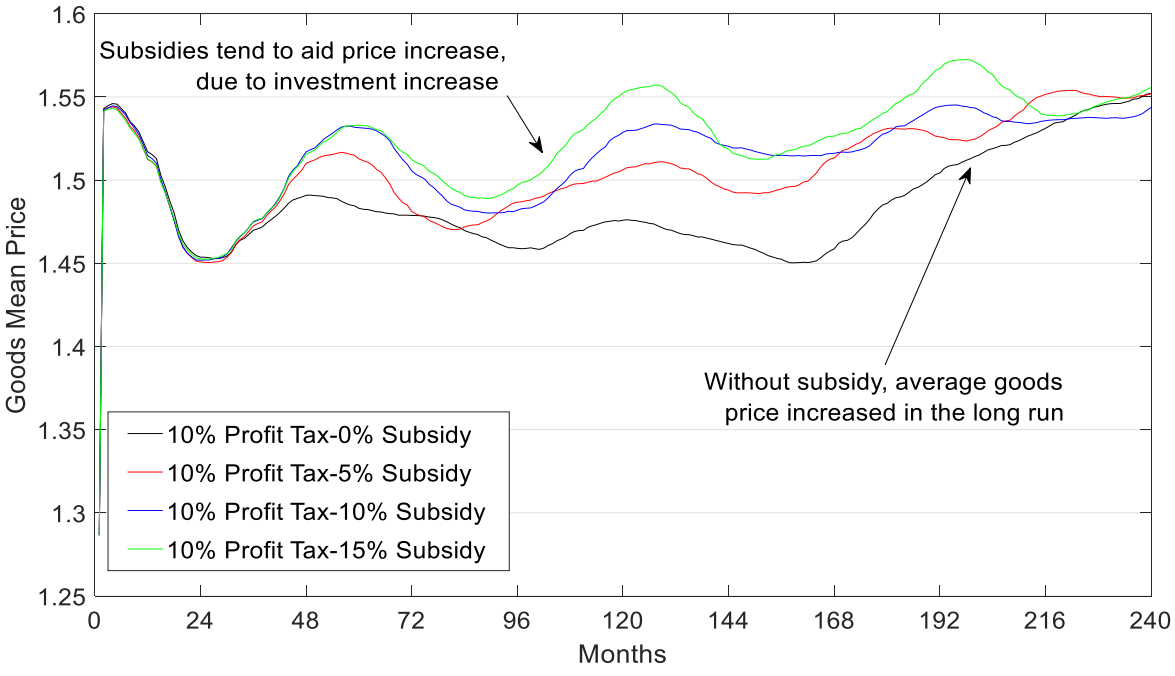

Figure 3: Overtime subsidy effect on average goods price at 50% unemployment benefit rate

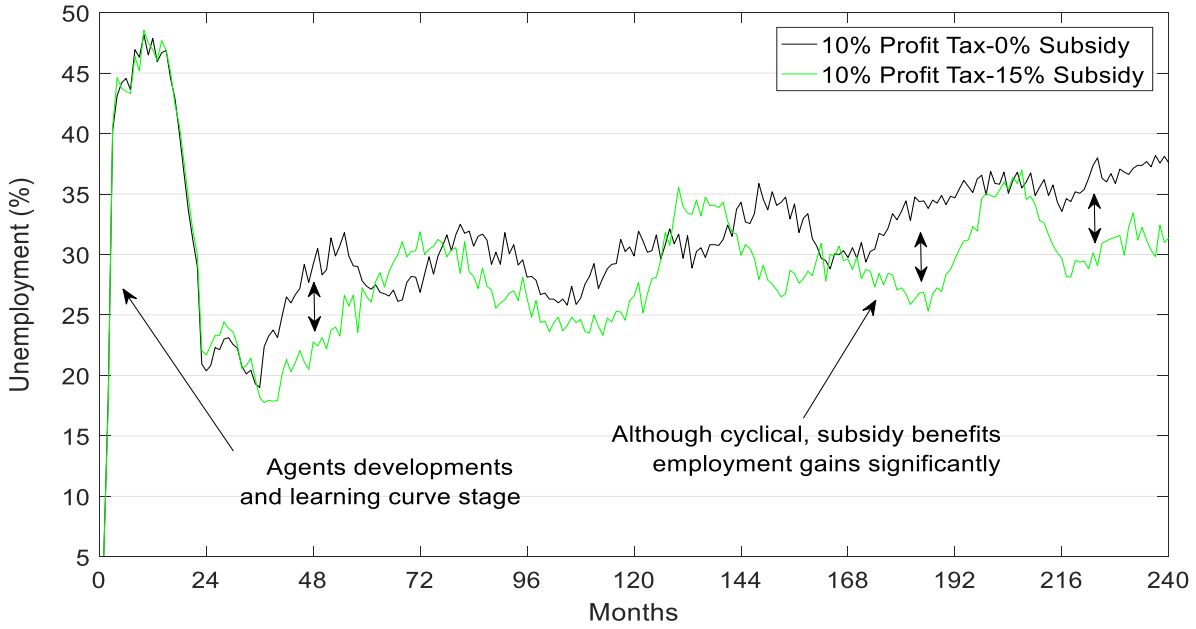

Figure 4: Overtime subsidy effect on employment at 50% unemployment benefit rate

If we consider the response of other macroeconomic phenomena such as wage margins, the reduction of which has a potential to reduce wage and income inequality concerns of many developing countries. Figure 5 presents the results of the inquest into this. The result presents a 20-year average rather than progression over the subsequent 20 years (as in Figures 1 to 4). This allows us to compare variations in investment subsidy rate, profit tax rate, and unemployment benefit rate, and examine the overall response in the economy. We see that higher unemployment benefit rates reduce wage margins and lead, and this reduction is more evident when combined increases in subsidy. More importantly, Figure 5 confirms increases in average wage levels owing to higher profit tax rates (10%, 20%), higher unemployment benefit or higher subsidy rates. Findings support suggestions [51] that subsidies aid wage increases. This was after authors investigated the impact of public subsidies on business enterprise research in selected OECD countries.

Real wage is calculated as nominal wage over consumption goods price ($Wage_T^R = \sum_i^n \frac{N^{wage}}{\bar{p}^{goods}}$), indicating the role of the price level on household behaviour. Within this model, and in assessing the potential of a policy such as unemployment benefits in a developing economy setting, the indirect role of such a benefit, in addition to the income sourced from investment dividends, and bond interest, all come together to form household income. As such, with increasing social benefits, real wage margins and or patterns are indicative of positive or negative economic impacts. Figure 5 suggests that increasing social benefits reduce the wage gap, but drive down wages, while the introduction of investment subsidies increases wage levels. These subsidy additions contribute to cyclical increases in goods prices (Figure 3), which may be linked to increasing investment levels (Figure 6).

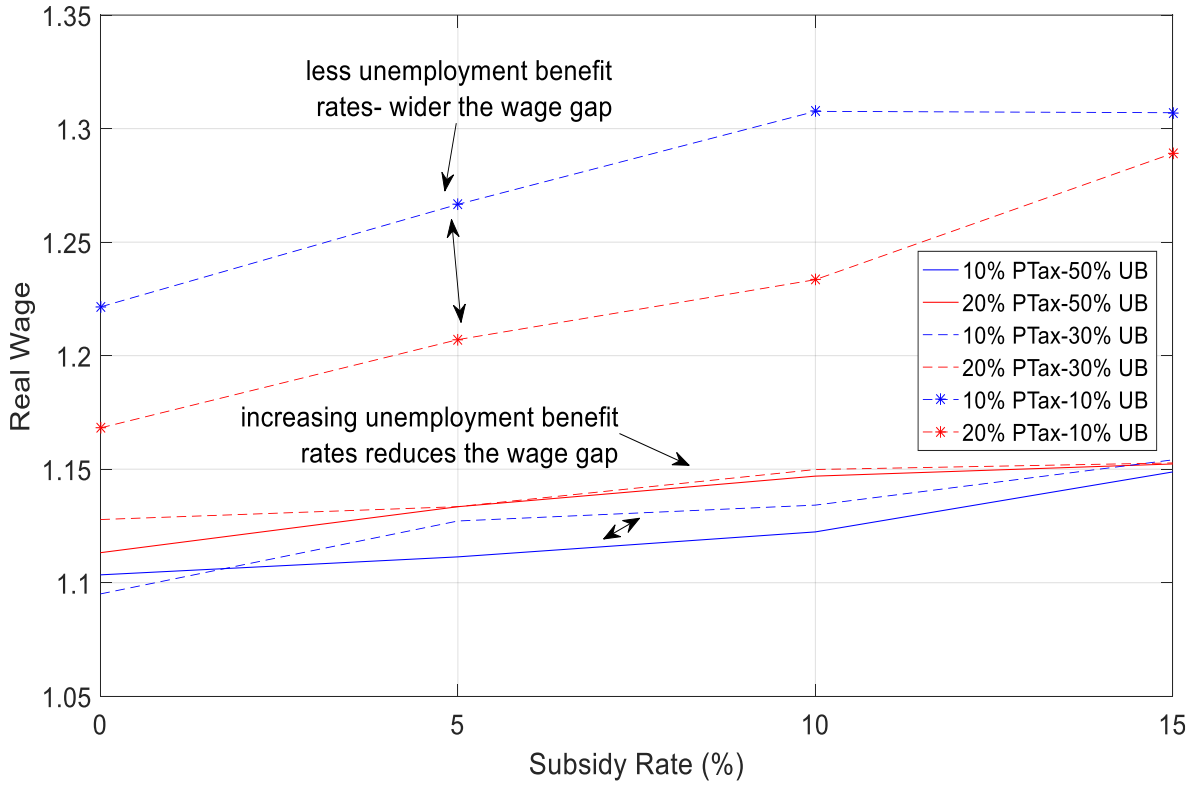

Figure 5: 20 year averages for Wage.

In Figures 6 and 7, further analysis of changes in investment, wages and employment due to policy changes in the system and the sensitivity thereof are compared, by varying the levels of unemployment benefits. Although it is literature suggest that efficiency improves as subsidies and investment gains increase, Figure 8 shows that a minimal increase in energy production levels as investment subsidies go up. The more sensitive energy production however comes in the presence of much lower unemployment benefits in the system. A possible reason for this, is the fact that in many developing countries, energy production endeavours are carried out by the state, with the main power company being a state owned company. As such increased state welfare demands may result in substitution of funds from one endeavour to the other.

The results obtained from the ABM simulations are quite vast given the comprehensive nature of the economic environment of the model. The paper focuses on a few of the variables of interest. The simulations show, for example, an increase in the wage gap (Figure 5) as unemployment benefits reduce from 50% to 10% while the subsidy rate remains constant. Lower unemployment benefits and profit taxes (as opposed to higher levels of unemployment benefits and profit taxes) cause firms to become more sensitive to an increase in subsidies. Finally, in contrast to empirical evidence, the simulation results show a decline in unemployment rates when unemployment benefits increase. However, the decline in unemployment does not continue diminishing as unemployment benefits rise.

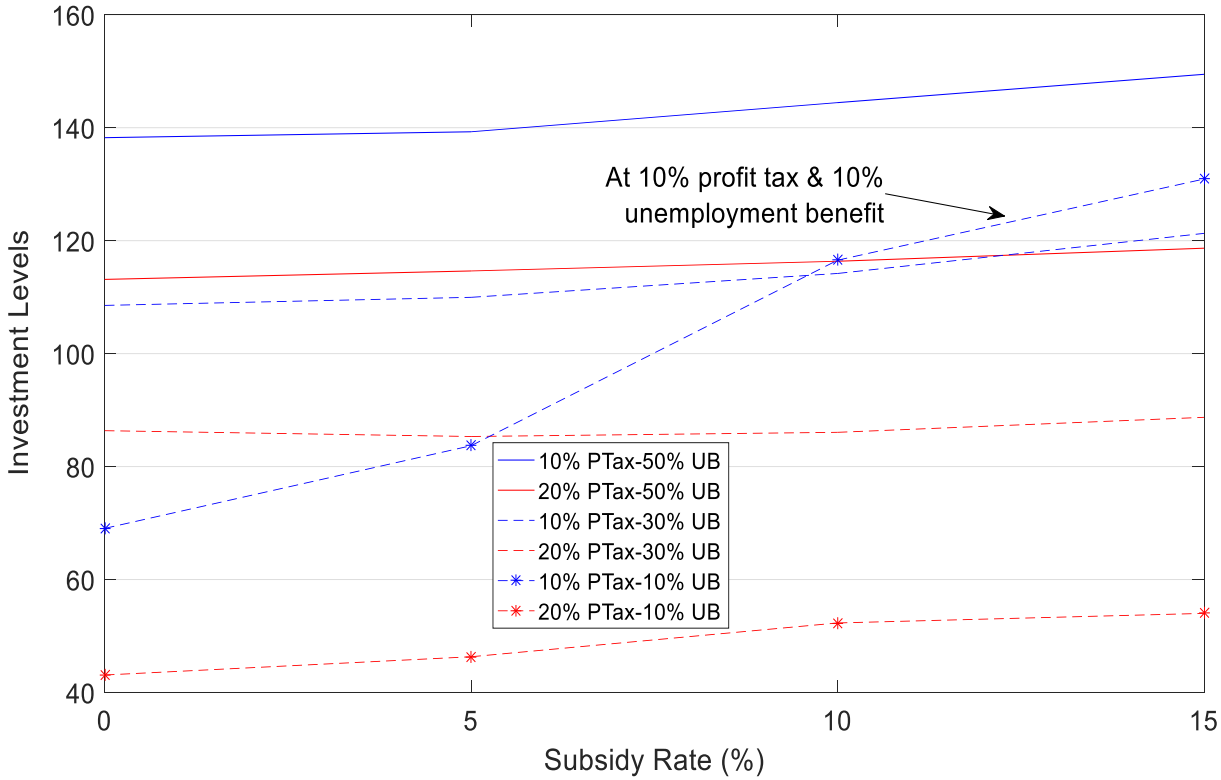

Figure 6: 20 year averages for investment. PTax denotes profit tax and UB represents unemployment benefit rate

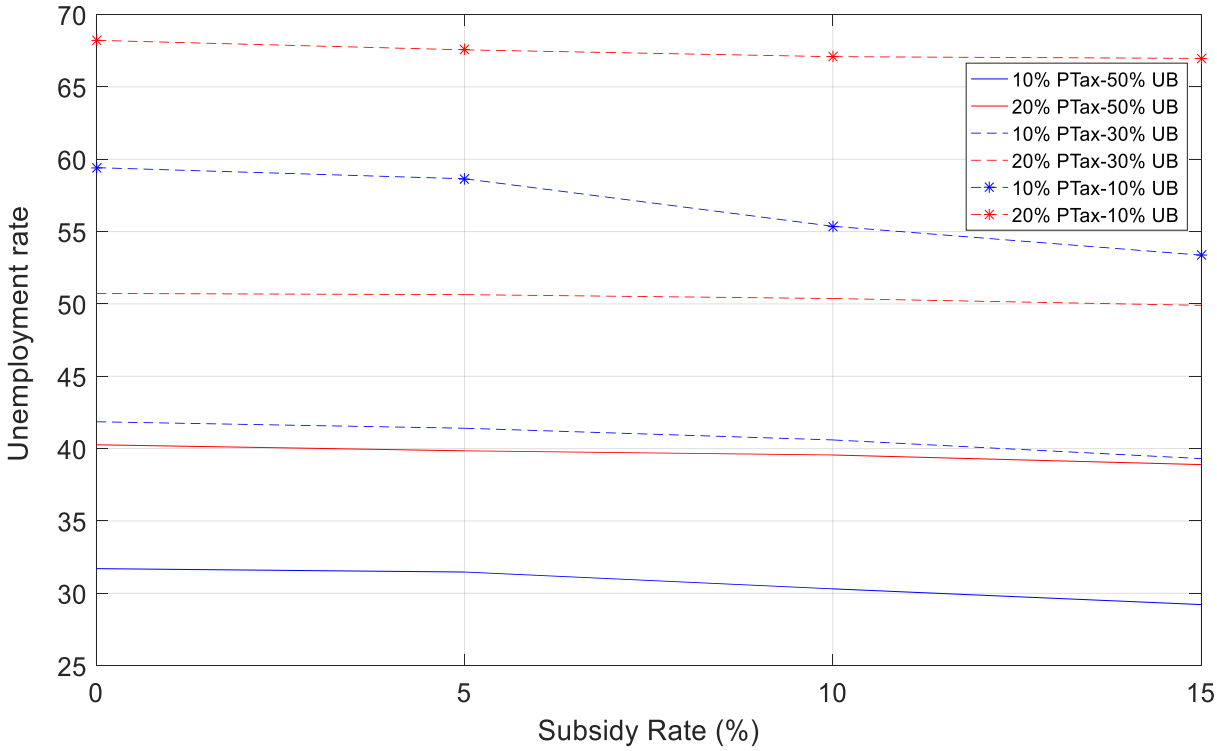

Figure 7: 20 year averages for unemployment rate

4.1 Investment decision – reflection on employment

With 10% profit tax providing the better initial scenario performance, the next scenario outputs focus on average trends under 10% profit tax system. In Figure 9- environments with lower unemployment benefit structures are more responsive and or sensitive to investment subsidies. Using individual seed average of 20-year simulation period, a boxplot merges energy tax levies for comparison across subsidy rates due to investment decisions and resulting employment gains. The boxplot shows sensitivity spread in investment and employment levels according to energy tax rates, which display max and min observations along with median (straight line in box) and mean (symbolic representations ▪▼*×♦ for 10%, 20%, 30%, 40% and 50% unemployment benefit rates respectively) points. Outliers (red cross symbol) are produced to signal significant presence of result deviations and hint at questionable data outputs.

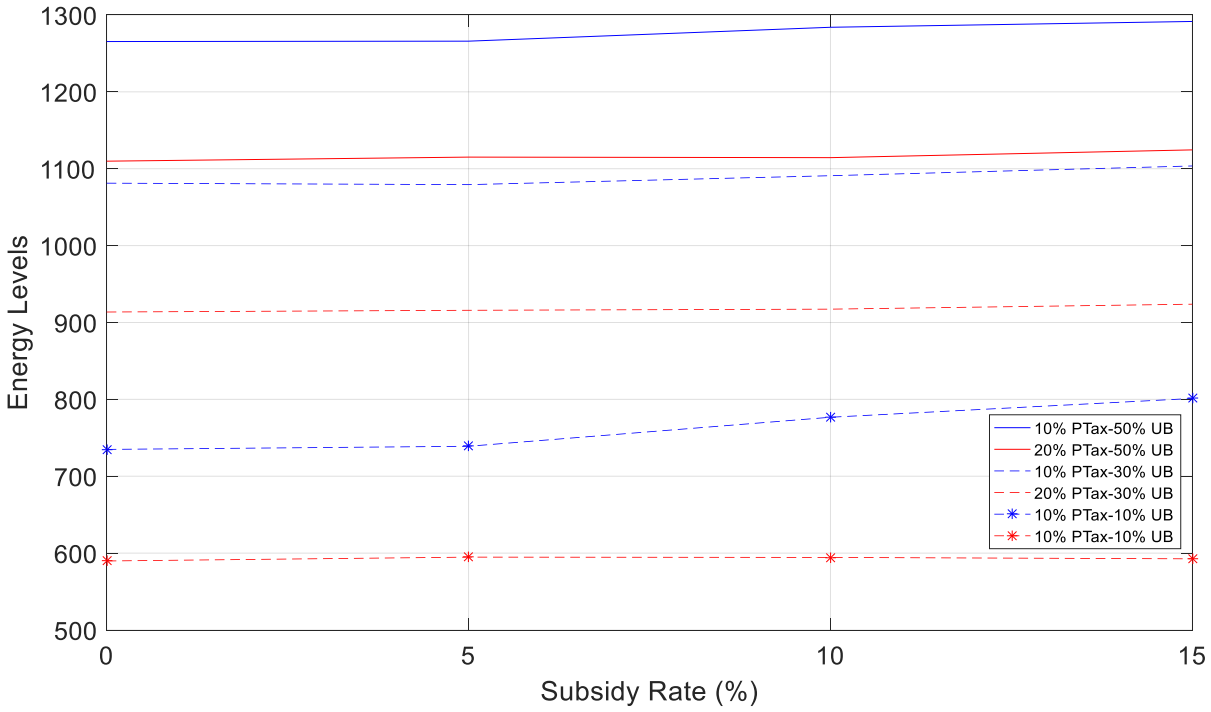

Figure 8: 20 year averages for Energy demand

Although boxplots are more adaptable to large scale data, they can be adopted for smaller data too and further ease identification of extreme points and homogeneity in data. It permits easier view of spread between data outputs. The 10% UB produced the larger box spread or stretch, signalling it as the most responsive to subsidy addition and energy price hikes. With further increase in UB, results suggest lower unemployment benefit scenarios are more sensitive and or responsive to subsidy additions and energy tax. The sensitivity spreads with energy price hikes is evident from 10%-30% UB. These suggest environments with lower social benefits are more prone to climate policies – in the form of energy tax and transmission of energy price shocks. Incentive policies prove effective towards stimulating resource

efficient investment irrespective of the selected unemployment benefit rate. In addition, the combined subsidy policy with improved unemployment benefits produced suggest economic improvement reflected in unemployment reduction, due to production sales. This suggests a properly regulated structure towards attaining effective subsidy goals.

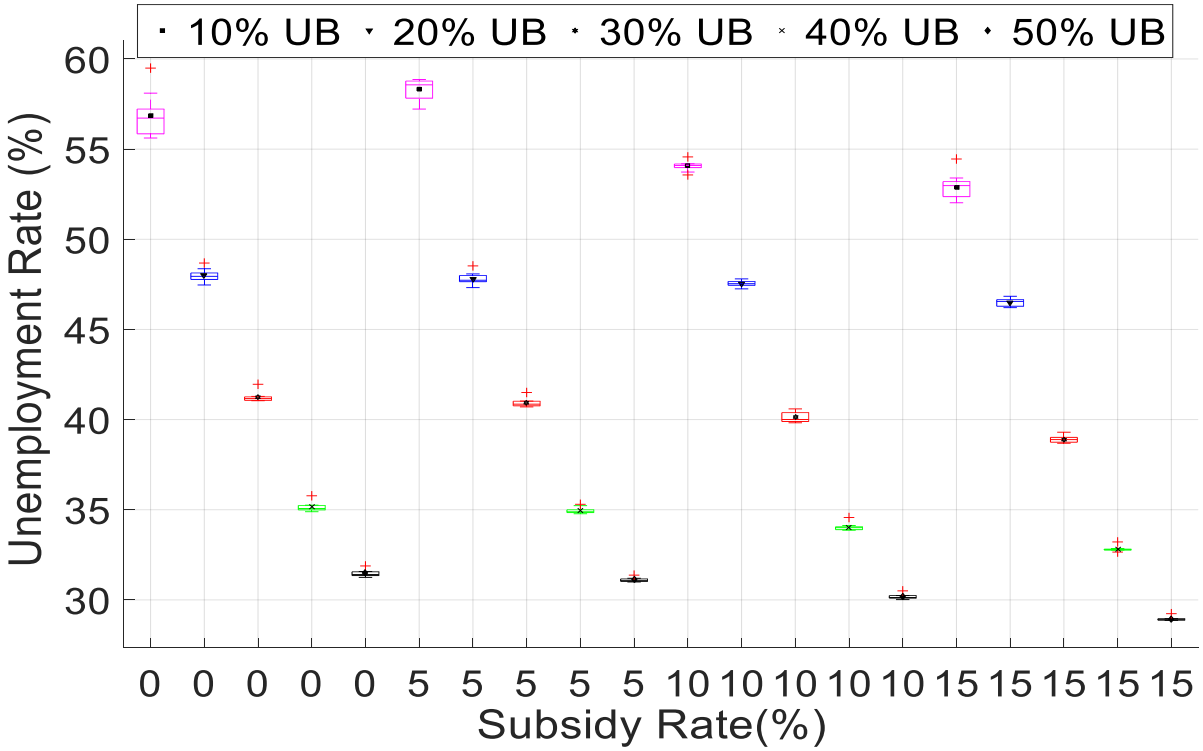

Figure 9: Unemployment rate boxplot – Subsidy and Energy Tax inclusion

5 Conclusion

In this paper, we employed the ABM approach to assess the interplays between three different policies: unemployment benefits, investment subsidies and energy taxes. The goal was to approach some empirically tested questions, which are often limited by data availability, by simulating a comprehensive economic environment adapted for a developing economy. Within an ABM, the impact of a policy initiative can be traced and observed for all possible macroeconomic outcomes, allowing for a wholesome assessment of the potential impact of policy initiatives and the uncovering of a lot more information. This information could be used to design policies adequately, and to limit the negatives and maximise the positives thereof. In this regard, we find that increased unemployment benefits have a diminishing impact on the unemployment rate, and as investment subsidies go up, the impact they have on reducing the wage gap is a positive return. In such instances developing countries can determine which agenda is of most immediate importance and design such policies to meet the immediate need or target of the economy.

We also found that the sensitivity of investment level to subsidy changes increases as the level of unemployment benefits rises. However, this only occurs until a threshold of about a 30% unemployment benefit is reached. Beyond this point, the impact on investment sensitivity reduces as unemployment benefits rise. This suggests that developing countries should keep unemployment benefits should in the region of 30% in order to limit the sometimes negative labour market impact of such a policy. An investigation of increases in energy investments and energy taxes over the 20-year period shows that reform in the energy sector is achievable, and should not impact the investment adversely in the long run. However, in the short term the negative impact will be significant.

This simulation activity attempted to exploit the ease of applying open ABM for policy case studies. It must be noted that, while the ABM approach allows us to analyse the interplays between several sectors of the economy, which is an often impossible task with empirical analysis, the outcomes of such an approach are highly dependent on the predefined economic environment. This means that some of the definitions are needed from previous empirical analysis to make the model more realistic and accurate. For large models with several market representations, the model's accuracy for a typical developing economy needs to be investigated cautiously, as the economic environments of diverse developing economies differ significantly. Further, as a model created by another modeller, some functions may be misinterpreted. Therefore, the way forward would be to build more representative ABMs for individual countries. Unique country characteristics should be included in the model to achieve much more realistic, relevant and accurate simulation outcomes. A challenge that might arise is the amount of time needed to learn and apply an existing model or to build a new representational model.

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Appreciation is extended to University of Genoa, Department of Mechanical Engineering, Energetics, Management and Transportation (DIME) for gaining research training on Agent based model and sustainability integration. Additional gratitude is channelled to University College Cork, Environmental Research Institute for encouraging research work on Agent based modelling opportunity. The knowledge gained during these times contributed to the transition suggestions with respect to agent-based modelling and simulation.

Reference

1. Assembly, U.G., *Transforming Our World: The 2030 Agenda for Sustainable Development. Resolution adopted by the General Assembly on 25 September 2015.* New York: United Nations, http://www. un. org/ga/search/view_doc. asp, 2015.
2. Farmer, J.D. and D. Foley, *The economy needs agent-based modelling.* Nature, 2009. **460**(7256): p. 685-686.
3. Macal, C.M. and M.J. North, *Tutorial on agent-based modelling and simulation.* Journal of simulation, 2010. **4**(3): p. 151-162.
4. Snape, J.R., P.J. Boait, and R. Rylatt, *Will domestic consumers take up the renewable heat incentive? An analysis of the barriers to heat pump adoption using agent-based modelling.* Energy Policy, 2015. **85**: p. 32-38.
5. Epstein, J.M., *Agent-based computational models and generative social science.* Complexity, 1999. **4**(5): p. 41-60.
6. Epstein, J.M. and R. Axtell, *Growing artificial societies: social science from the bottom up*. 1996: Brookings Institution Press.
7. Tesfatsion, L. *Agent-based computational economics: A brief guide to the literature*. in *Reader's Guide to the Social Sciences, Volume 1, Fitzroy-Dearborn*. 2001. Citeseer.
8. Dawid, H., et al., *Agent-based macroeconomic modeling and policy analysis: The eurace@ unibi model.* 2014.
9. Cincotti, S., M. Raberto, and A. Teglio, *Credit money and macroeconomic instability in the agent-based model and simulator Eurace.* 2010.
10. Dawid, H., et al., *The eurace@ unibi model: An agent-based macroeconomic model for economic policy analysis.* 2012.
11. Arni, P., R. Lalive, and J.C. Van Ours, *How effective are unemployment benefit sanctions? Looking beyond unemployment exit.* Journal of Applied Econometrics, 2013. **28**(7): p. 1153-1178.
12. Barro, R., *The folly of subsidizing unemployment.* Wall Street Journal, 2010. **30**.
13. Mitman, K. and S. Rabinovich, *Do Unemployment Benefit Extensions Explain the Emergence of Jobless Recoveries?* Unpublished manuscript, 2014.
14. Solon, G., *Labor supply effects of extended unemployment benefits.* The Journal of Human Resources, 1979. **14**(2): p. 247-255.
15. Bergström, F., *Capital subsidies and the performance of firms.* Small Business Economics, 2000. **14**(3): p. 183-193.
16. Tzelepis, D. and D. Skuras, *The effects of regional capital subsidies on firm performance: an empirical study.* Journal of Small Business and Enterprise Development, 2004. **11**(1): p. 121-129.
17. Fölster, S., *Do subsidies to cooperative R & D actually stimulate R & D investment and cooperation?* Research Policy, 1995. **24**(3): p. 403-417.
18. González, X. and C. Pazó, *Do public subsidies stimulate private R&D spending?* Research Policy, 2008. **37**(3): p. 371-389.
19. Hussinger, K., *R&D and subsidies at the firm level: An application of parametric and semiparametric two-step selection models.* Journal of applied econometrics, 2008. **23**(6): p. 729-747.
20. Lach, S., *Do R&D subsidies stimulate or displace private R&D? Evidence from Israel.* The journal of industrial economics, 2002. **50**(4): p. 369-390.
21. Ginneken, W., *Extending social security: Policies for developing countries.* International Labour Review, 2003. **142**(3): p. 277-294.
22. Wibbels, E. and J.S. Ahlquist, *Development, trade, and social insurance.* International Studies Quarterly, 2011. **55**(1): p. 125-149.
23. Oketch, M.O., *Determinants of human capital formation and economic growth of African countries.* Economics of Education Review, 2006. **25**(5): p. 554-564.
24. Onaolapo, A.A. and S.O. Kajola, *Capital structure and firm performance: evidence from Nigeria.* European Journal of Economics, Finance and Administrative Sciences, 2010. **25**: p. 70-82.

25. Maina, L. and M. Ishmail, *Capital structure and financial performance in Kenya: Evidence from firms listed at the Nairobi Securities Exchange.* International Journal of Social Sciences and Entrepreneurship, 2014. **1**(11): p. 209-223.
26. Jayne, T. and S. Rashid, *Input subsidy programs in sub-Saharan Africa: a synthesis of recent evidence.* Agricultural economics, 2013. **44**(6): p. 547-562.
27. Collins, A. and J. Snowball, *Transformation, job creation and subsidies to creative industries: the case of South Africa's film and television sector.* International Journal of Cultural Policy, 2015. **21**(1): p. 41-59.
28. Wentzel, M.S.I. and M. Steyn, *Investment promotion in the South African manufacturing industry: incentive comparisons with Malaysia and Singapore.* South African Journal of Economic and Management Sciences, 2014. **17**(3): p. 319-335.
29. Flatters, F., *The economics of MIDP and the South African motor industry*. 2005: Trade and Industrial Policies Strategies.
30. Kaplan, D. *Manufacturing performance and policy in South Africa–A review*. in *TIPS/DPRU Forum*. 2003.
31. Beg, N., et al., *Linkages between climate change and sustainable development.* Climate policy, 2002. **2**(2-3): p. 129-144.
32. Grindle, M.S., *Good enough governance: poverty reduction and reform in developing countries.* Governance, 2004. **17**(4): p. 525-548.
33. Nickell, S., *Unemployment and labor market rigidities: Europe versus North America.* The Journal of Economic Perspectives, 1997. **11**(3): p. 55-74.
34. Bronzini, R. and G. de Blasio, *Evaluating the impact of investment incentives: The case of Italy's Law 488/1992.* Journal of urban Economics, 2006. **60**(2): p. 327-349.
35. Malleson, N., A. Heppenstall, and L. See, *Crime reduction through simulation: An agent-based model of burglary.* Computers, environment and urban systems, 2010. **34**(3): p. 236-250.
36. Bloomquist, K.M., *A comparison of agent-based models of income tax evasion.* Social Science Computer Review, 2006. **24**(4): p. 411-425.
37. Robinson, D.T., et al., *Comparison of empirical methods for building agent-based models in land use science.* Journal of Land Use Science, 2007. **2**(1): p. 31-55.
38. d'Aquino, P., et al. *Agent-based models of land-use and land-cover change*. in *Proc. of an International Workshop*. 2002. Citeseer.
39. Valbuena, D., P.H. Verburg, and A.K. Bregt, *A method to define a typology for agent-based analysis in regional land-use research.* Agriculture, Ecosystems & Environment, 2008. **128**(1): p. 27-36.
40. Heckbert, S., T. Baynes, and A. Reeson, *Agent-based modeling in ecological economics.* Annals of the New York Academy of Sciences, 2010. **1185**(1): p. 39-53.
41. Janssen, M.A., *Agent-based modelling.* Modelling in ecological economics, 2005: p. 155-172.
42. Ziervogel, G., et al., *Agent-based social simulation: a method for assessing the impact of seasonal climate forecast applications among smallholder farmers.* Agricultural Systems, 2005. **83**(1): p. 1-26.
43. Stern, P.C., *Individual and household interactions with energy systems: toward integrated understanding.* Energy Research & Social Science, 2014. **1**: p. 41-48.
44. Fouquet, R., *Lessons from energy history for climate policy: Technological change, demand and economic development.* Energy Research & Social Science, 2016. **22**: p. 79-93.
45. Gottschalk, R., *Institutional Challenges for Effective Banking Regulation and Supervision in Sub-Saharan Africa.* 2014.
46. Nyantakyi, E.B. and J. Munemo. *Technology Gap, Imported Capital Goods and Productivity of Manufacturing Plants in Sub-Saharan Africa*. in *African Economic Conference*. 2014.
47. Dawid, H., et al., *Eurace@ unibi model v1. 0 user manual.* 2011.
48. Bazilian, M., S. Nakhooda, and T. Van de Graaf, *Energy governance and poverty.* Energy Research & Social Science, 2014. **1**: p. 217-225.
49. Nicholson, W. and K. Needels, *Unemployment insurance: Strengthening the relationship between theory and policy.* The Journal of Economic Perspectives, 2006. **20**(3): p. 47-70.
50. Kroft, K. and M.J. Notowidigdo, *Should unemployment insurance vary with the unemployment rate? Theory and evidence*. 2011, National Bureau of Economic Research.

51. Wolff, G.B. and V. Reinthaler, *The effectiveness of subsidies revisited: Accounting for wage and employment effects in business R&D.* Research Policy, 2008. **37**(8): p. 1403-1412.

Appendix

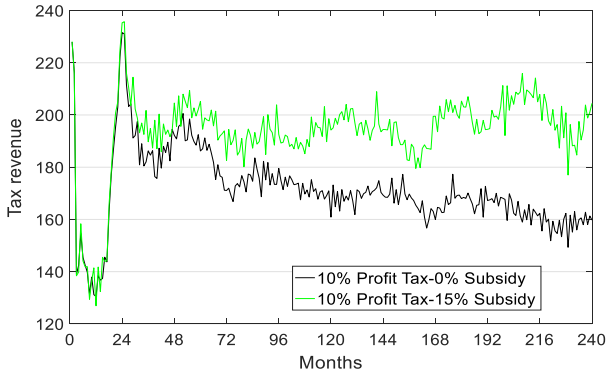

Figure a1: Subsidy benefits in tax revenue at 30% UB

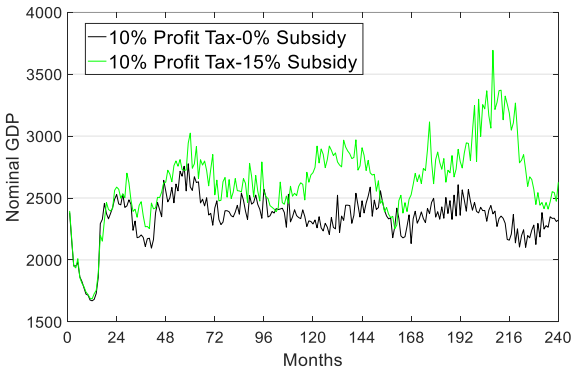

Figure a2: Subsidy benefits in GDP at 30% UB

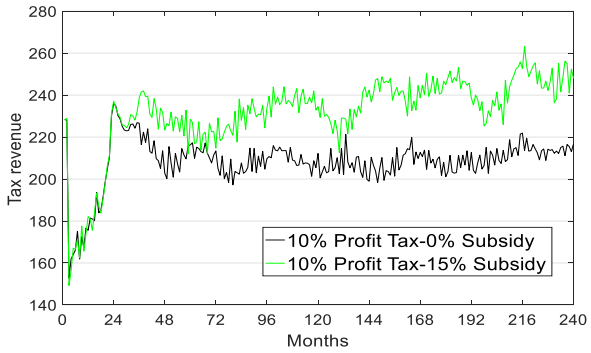

Figure a3: Subsidy benefits in tax revenue at 50% UB

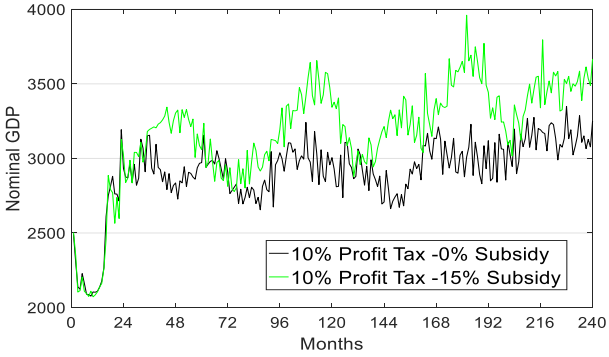

Figure a4: Subsidy benefits in GDP at 50% UB

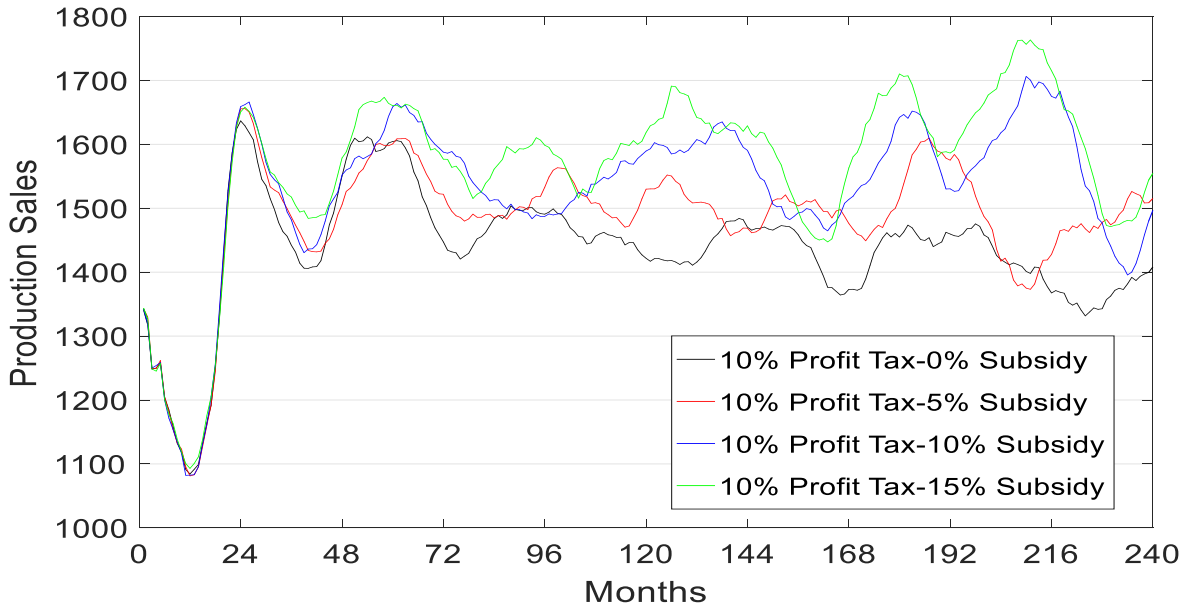

Figure b: Confirmation of production sales benefits in simulation trial at 30% Unemployment benefit rate

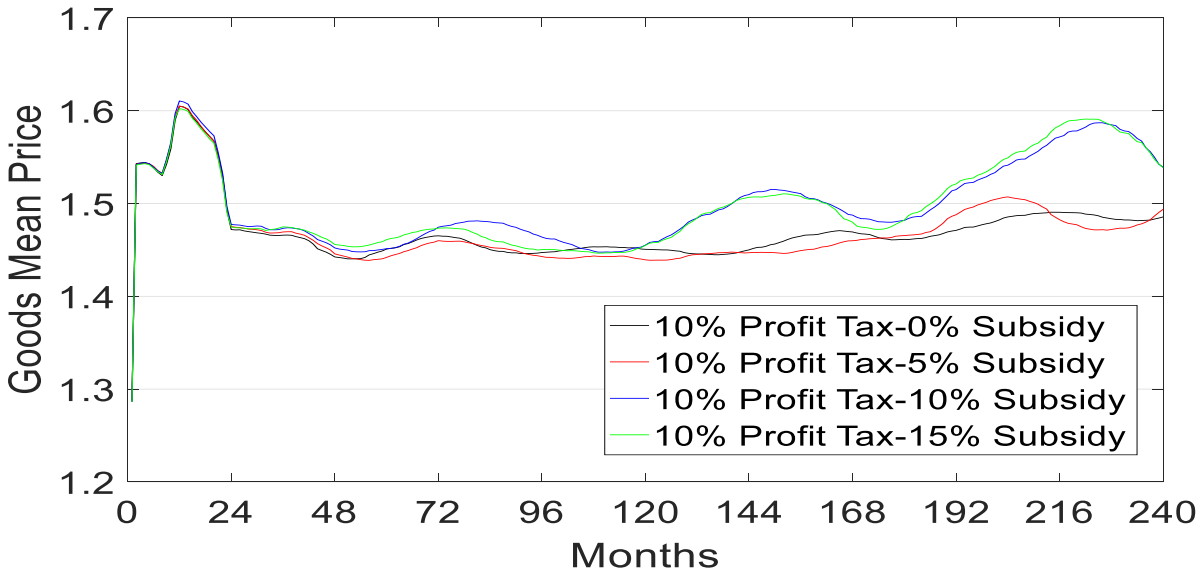

Figure c: Overtime subsidy effect on average goods price at 30% unemployment benefit rate

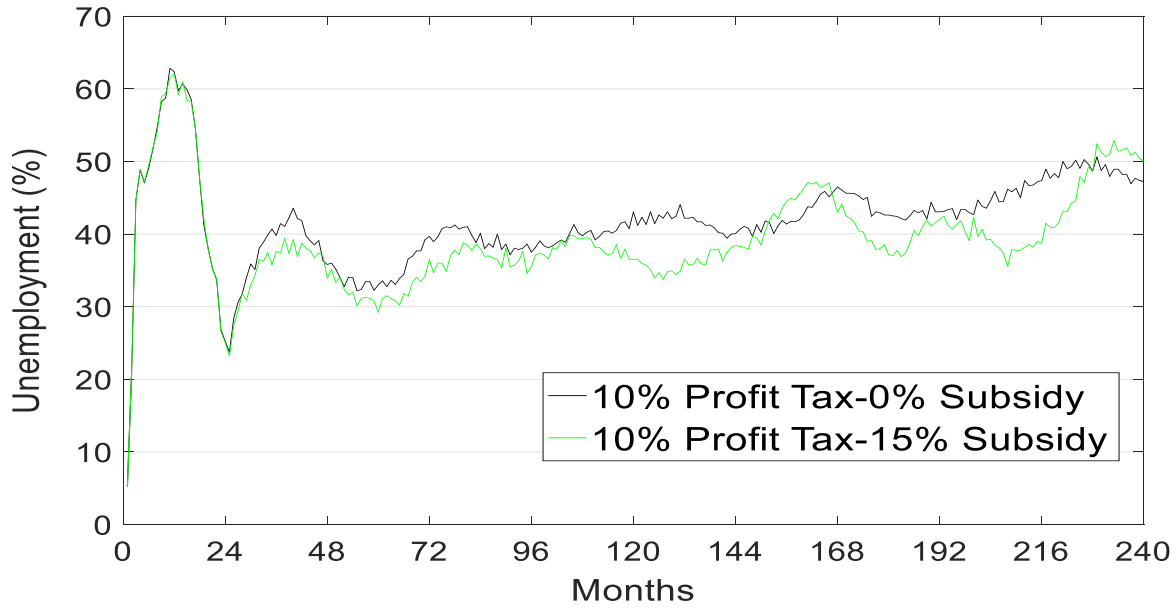

Figure d: Overtime subsidy effect on employment at 30% unemployment benefit rate