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Cem Oyvat (University of Greenwich)

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Corresponding author

Cem Oyvat, Senior Lecturer in Economics, University of Greenwich, Department of Economics and International Business, Old Royal Naval College Park Row, SE10 9LS, London, United Kingdom, e-mail: c.oyvat@greenwich.ac.uk

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This paper aims to examine the impact of minimum wages on aggregate demand and employment using a demand-led post-Kaleckian growth model. Benefitting from previous empirical work on wage- and profit-led growth and minimum wages, the model considers the impact of minimum wages on consumption, investment, and net exports through its effects on informality, prices, labour productivity, and distribution between workers and capitalists. The paper shows that higher minimum wages could lead to higher aggregate demand in the short run through higher consumption and investments in labour-saving technologies, which could reduce the possible negative effects of minimum wages on employment or create additional employment. If higher minimum wages have a strong impact on informality, then the impact of minimum wages on consumption and net exports is less positive and less negative, respectively. Higher minimum wages are also likely to increase labour productivity in both the short and medium run, which would have further effects on aggregate demand, employment, and prices. Finally, higher minimum wages are likely to affect aggregate demand and employment in small open economies more negatively or less positively.

1 Introduction

This paper aims to examine the impact of minimum wages on economic growth and employment using a demand-led post-Kaleckian growth model. The model considers the impact of minimum wages on consumption, investment, and net exports through the effect of minimum wage on formal and informal employment, labour productivity, distribution between workers and capitalists and prices. The paper highly benefits from previous empirical work on wage- and profit-led growth and the effect of minimum wages on employment, informality, and inflation¹.

Evidence on the relationship between minimum wage and employment is mixed. A wide number of studies (Card and Krueger, 1994; Cengiz et al., 2019; Dube, 2019a; Broecke, Fortia

¹Lemos's(2008) literature review on the relationship between minimum wages and prices notes that "Most studies utilize regression analysis; however, they very rarely discuss the theoretical model that delivered their empirical equation specification". This paper also aims to narrow the gaps between the theoretical and empirical literature on minimum wages by building a theoretical model that highly benefits from empirical work.

and Vandeweyer, 2017) have found that an increase in minimum wage does not lead to a significant decline in employment, while many papers have found that minimum wages have small or larger negative effects on employment (Dube, 2019a). The monopsonic labour markets is the main theoretical explanation for the weak relationship between minimum wages and employment.

This paper aims to contribute to the theoretical literature by suggesting demand and productivity as additional mechanisms on the impact of minimum wages on employment. In some countries, minimum wage workers constitute a significant share of employees. In 2021, 32.2% of the employees in Turkey earned minimum wages to 110% of the minimum wage (Disk-Ar, 2022) and in 2017, 20-21% of the employees in Romania, Portugal and Hungary earned 90% to 110% of the minimum wage (Eurofound, 2020). The influence of minimum wages on aggregate demand would be especially strong in countries with significant shares of minimum wage workers considering its direct effects and its effects through spillovers on higher wages.

Moreover, it aims to contribute to the post-Kaleckian literature by introducing a minimum wage to a demand-led model. The model aims to explain the impact of minimum wage shocks on both developed and developing economies.

Section 2 reviews the theoretical and empirical literature on the effects of minimum wages, average wages, and wage share on employment, aggregate demand, productivity and inflation. Section 3 builds a post-Kaleckian growth model with minimum wage by benefitting from previous theoretical and empirical literature. Section 4 discusses different possible cases based on the assumptions of the model. Finally, Section 5 concludes the paper.

2 Literature review

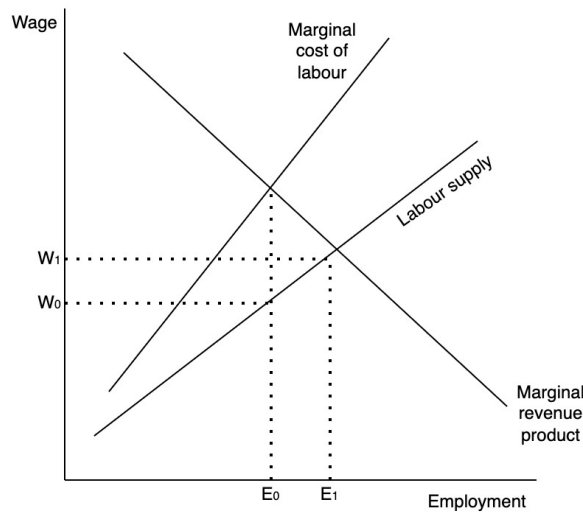
2.1 Minimum wages and employment

The effect of minimum wages in a monopsonic labour market setting was first discussed by Robinson(1933), who showed that higher minimum wages could indeed affect employment positively. Stigler(1946) also writes that in a competitive market, higher minimum wages reduce output and employment because workers with a marginal product lower than the new minimum wage will be made redundant. Moreover, higher minimum wages will push companies to adopt new techniques that further increase productivity and reduce employment. However, if the employer has significant control over wages, higher minimum wages will improve output and employment, as wages will approach the marginal product.

Card and Krueger(1995) explain the non-negative effect of minimum wages through the monopsonic structure of labour markets. Increases in minimum wages also raise the recruiting rate, which slightly increases employment; however, the firm would have to cut employment if the minimum wage increases above a certain level. Higher minimum wages increases the labour supplied(Manning, 2021).

As shown in Figure 1, in a monopsonic labour market without minimum wages, the em-

Figure 1: Minimum wages in basic(textbook) model of monopsony



ployment and wages would be at E_0 , at which marginal cost of labour and marginal product of labour are equal. The equilibrium wage in this setting is w_0 . However, if a minimum wage of w_1 is introduced, the minimum wage not only pulls the equilibrium wages up to w_1 , it also increases employment to E_1 .

Card and Krueger(1995) and Manning(2011) refer to this model as “the textbook model of monopsony.” However, the limitation of this basic monopsony model is that it follows the assumption of full employment and does not consider the minimum wages’ impact on labour demand. Indeed, a higher minimum wage could also influence labour demand through its influence on aggregate output.

In addition to the monopsony models, Manning (2021) and Schmitt (2015) discuss that higher minimum wages also reduce the turnover ratio, which could reduce the turnover costs for firms. Therefore, a small increase in the minimum wage might not have any effect on labor costs and employment.

Empirical evidence on the impact of minimum wages is mixed. Although several studies find that minimum wages influence employment negatively, a large number of papers find insignificant or even positive effects of minimum wages on employment(Dube, 2019a; Card and Krueger, 1994; Cengiz et al.,2019; Broeckea, Fortia and Vandeweyer, 2017).

Minimum wages could also have different effects on employment in different types of firms. Cengiz et al.(2019) estimate that minimum wages have a negative effect on employment in the tradable sector in the US, although they do not find a significant negative impact of minimum wages on total employment. Harasztosi and Lindner(2019) find that the minimum wage hike in Hungary decreased employment in firms with a higher labour share and in exporting firms. Hau, Haung and Wang(2020) estimates that higher minimum wages reduced employment especially in foreign firms and firms with low TFP.

Finally, minimum wage hikes can also influence informality, especially in developing economies. For India, Mansoor and O’Neill(2021) and, for Turkey, Işık, Tekgüç and Orhangazi(2020) es-

timate that minimum wages increase informality, although they do not reduce overall employment. Ham(2017) finds that higher minimum wages reduced formal employment and increased informal employment in Honduras. In a meta-analysis, Broeckea, Fortia and Vandeweyer(2017) for a number of development economies find that higher minimum wages lead to small increases in informal employment, although some of the estimations give insignificant outcomes.

2.2 Minimum wages, wages and distribution

Empirical work on minimum wages predominantly finds that minimum wage hikes also increase wages overall, as expected. However, the influence of the minimum wages is different for different wage groups.

For Mexico, Perez(2020) estimates that higher minimum wages only increase formal and informal wages close to the minimum wage. The positive impact is larger for formal wages. For Hungary, Harasztosi and Lindner(2019) find higher minimum wages also increase average wages. For Ecuador, Wong (2018) estimates that higher minimum wages increase wages in the treated group and that the impact is lower for women workers. Hau, Haung and Wang(2020) finds that higher minimum wages increases average wages in lower wage firms more in China. For India, Mansoor and O’Neill(2021) find that minimum wages increase daily wages in full-compliance regimes; however, higher rates of non-compliance reduce the positive effects of minimum wages on overall wages. However, the impact of minimum wages on consumption is strong in full-compliance regimes.

Pollin and Wicks-Lim(2016) estimates that the minimum wage increase in 2013 in the US reduced wage inequality amongst the fast food workers. Dube(2019a) estimates that an increase in minimum wages particularly reduces poverty at the bottom half of the distribution in the US, with the highest long-run minimum wage elasticities at the tenth and fifteenth quantiles of family incomes, which also shows the positive effects of minimum wages on overall income distribution.

Draga, Machin and Van Reenen(2011) estimate that the introduction of minimum wages in the UK in 1999 raised wages and significantly reduced profitability (profits/sales), especially in industries with relatively high market power. Drucker, Mazirov and Neumark(2021) find that higher minimum wages reduced profits of companies in Israel; however, the profits declined more in low-income companies.

2.3 Minimum wages and demand

The impact of minimum wages on aggregate demand is examined significantly less in the literature compared to the studies that examine its effects on employment. In the preface of twentieth-anniversary edition of *Myth and Measurement*, Card and Krueger(2016) also underline that “by shifting low-income households with a relatively high marginal propensity to consume, the minimum wage can increase aggregate consumption. Especially at a time when many nations have experienced excess productive capacity, the minimum wage can increase ag-

gregate demand and raise economic activity”. Therefore, they highlight that “the consumption and general equilibrium effects of the minimum wage are important topics for future research.”

Although, the literature on minimum wages mainly focus the relationship between minimum wages and employment, there are several empirical studies that estimates the impact of minimum wages on household consumption, investments and exports. Mansoor and O’Neill(2021) estimate that higher minimum wages significantly increase consumption in India, although the effects are smaller in where levels of noncompliance are higher. Moreover, Aaronson, Agarwal and French(2012) find that a minimum wage hike in the US increases spending of households particularly led by purchases of vehicles, which are partially financed by collateralized debt. Alonso (2022) estimates that an increase in the minimum wages leads to a modest increase in nondurable consumption and Cooper, Luengo-Prado and Parker(2019) find that higher minimum wages raise home and away consumption in the US. Moreover, Leung(2021) estimates that rising minimum wages lead to growth in merchandise sales in poorer regions in the US.

Harasztosi and Lindner(2019) find that the minimum wage hike in Hungary also had a positive effect on capital stock both in the short and medium run. This shows that higher minimum wages also increased investment on labour saving technologies, which would both stimulate aggregate demand and increase productivity. Similarly, Hau, Haung, and Wang(2020) estimate that a higher minimum wage accelerates labour to capital substitution in foreign and private firms in China. The impact is larger on low wage firms.

Moreover, Harasztosi and Lindner(2019) find that the increase in minimum wages in Hungary disproportionately had greater significant negative effect on the revenues of and employment in exporting firms compared to all firms, which is consistent with the empirical estimations based on Post-Kaleckian models that predict that higher unit labour costs could reduce exports (Onaran and Galanis, 2014; Alarco, 2016; Blecker, Cauvel, and Kim, 2022; Onaran, Oyvatt and Fotopoulou, 2022b).

2.4 Minimum wages and inflation

In monopsony models, if minimum wages doesn’t affect employment, it also doesn’t increase the prices (Card and Krueger, 1995).

Empirical evidence on the effect of minimum wages on inflation is mixed. Campos-Vazquez and Esquivel(2020) estimates that doubling of minimum wages in Mexico did not have any positive significant effect on prices in the short-run. Leung(2021) estimates that a 10% increase in minimum raises grocery prices by 0.6% to 0.8% in the US. Similarly, Cooper, Luengo-Prado and Parker(2019) also find that minimum wages have a modest effect on prices in the US. However, according to Harasztosi and Lindner(2019)’s estimates, consumers paid for 74-77% of the cost of the minimum wage hikes in Hungary and only 23-26% of the minimum wages were compensated through declining profits of firms.

2.5 Minimum wages and productivity

Minimum wage hikes also lead to an increase in productivity through various channels. Hau, Haung and Wang(2020) find that higher minimum wages increase TFP in foreign and private firms in China. The impact is higher for foreign and low TFP firms, which shows that lower TFP firms tend to respond to rising minimum wage stronger to catch up with the industries' efficient frontier.

Hirsch, Kaufman and Zelenska (2015)'s survey shows that managers respond to minimum wage increases by increasing their performance standards. Moreover, minimum wages encourage employers to implement extensive training, job security provisions, and self-managed work teams by protecting them from low-wage competition. These measures could improve the long-term productivity of firms (Kaufman, 2010).

Higher minimum wages also reduce the turnover rates among low-wage workers, which also decreases productivity as newer staff are less trained for the job than the experienced staff (Pollin and Wicks-Lim, 2016).

2.6 Post-Keynesian/Kaleckian growth models with minimum wages

There are limited number of theoretical work with Post-Keynesian/Kaleckian growth models that considers minimum wage shocks. Brenck and Carvalho(2020) builds a two-sector (tradable and non-tradable) neo-Kaleckian growth model in which mark-ups in non-tradable sector are determined by minimum wages. Their model shows that an increase in minimum wages reduces wage inequality, leads to higher output share of non-tradable sector; however, it might lead to worsening trade balance.

In their Kaleckian model, Sasaki, Matsuyama and Sako(2013) show that introducing minimum wage could lead to higher wage and employment rates than the steady state equilibrium value in wage-led demand regimes under certain conditions. In profit-led demand regimes, minimum wages mitigate fluctuations; however, minimum wages could also lead to lower real wages and employment than in the steady state equilibrium conditions.

Heise and Pusch(2020) also develops a Post-Keynesian model with two sectors and support their model with empirical data from Germany. They estimate that the demand on sectors with higher share of minimum wages are less elastic to minimum wage increases. Therefore, the employment effects of minimum wages are only negative for the sector with larger share of minimum wages. In the sectors with small share of minimum wage workers, the effect of rising minimum wages through rising demand surpasses the direct negative effects of rising labour costs. Overall, the impact of introduction of binding minimum wage in 2015 is very small.

3 A demand-led model on minimum wages

3.1 The model

This section presents a demand-led post-Kaleckian growth model that examines the impact of minimum wages on aggregate demand, employment and prices. The aggregate demand (Y_t) at time t is the sum of consumption(C_t), investment(I_t), exports(X_t) and imports of goods and services(M_t).

$$Y_t = C_t + I_t + X_t - M_t \quad (1)$$

The model doesn't have government expenditures for simplicity. The employment market is divided into two types of workers, formally(F) and informally(I) employed workers². The informal workers, on average, receive wages lower than formal workers and could earn below minimum wages. The formal real wages(w_{Ft}) and informal real wages(w_{It}) are determined by nominal formal(W_{Ft}) and informal(W_{It}) wages and prices(P_t).

$$w_{Ft} = W_{Ft}/P_t \quad (2)$$

$$w_{It} = W_{It}/P_t \quad (3)$$

Total employment(E_t) is aggregate demand divided by labour productivity(T_t):

$$E_t = \frac{Y_t}{T_t} \quad (4)$$

Labour productivity is

$$T_t = t_0(Y_t)^{t_1}(Y_{t-1})^{t_2}(w_{Ft})^{t_3}(w_{F(t-1)})^{t_4}(w_{It})^{t_5}(w_{I(t-1)})^{t_6} \quad (5)$$
$$t_0, t_1, t_2, t_3, t_4, t_5, t_6 > 0$$

Higher output could increase labour productivity since increasing scale could lead to a more efficient allocation of resources($t_1, t_2 > 0$), which is known as the Verdoorn effect (Naastepad, 2006; Hein and Tarassow, 2010). As the new Keynesian efficiency wage theories (Shapiro and Stiglitz, 1984) indicate, higher wages could increase the effort of the workers and hence the labour productivity ($t_3 > 0$). Moreover, higher wages lead to an induced technical change towards labour-saving technologies, which aims to reduce unit labour costs(Naastepad, 2006; Taylor, 2004; Hein and Tarassow; 2010; Onaran, Oyvat and Fotopoulou,2022a, b). This is also known as Marx-biased technical change(Foley and Marquetti, 1997; Tavani and Zamparelli, 2021). Technical change towards labour-saving technologies increases labour productivity in the medium run ($t_4 > 0$). Moreover, higher minimum wages could lead to a rise in standards of performance(Hirsch, Kaufman and Zelenska, 2015), extensive staff training(Kaufman, 2010) and

²This is different from decomposing the economy as informal and formal sectors. The model considers that an enterprise could employ workers both formally and informally.

a lower turnover rate (Pollin and Wicks-Lim, 2016), which all would increase labour productivity.

The Verdoorn effect and the positive impact of wages on labour productivity discussed above are strongly supported by various empirical estimations (Naastepad, 2006; Hein and Tarassow, 2010; Onaran, Oyvatt and Fotopoulou, 2022b; Fontanari and Palumbo, 2023).

Minimum wages could be either determined as monthly minimum wages as in France, Spain and Turkey or as hourly minimum wages as in the United Kingdom, the United States and South Africa (WageIndicator Foundation, 2023). In this model, wages, employment and labour productivity should be taken as average wages per worker, the total number of workers and output/total number of workers in the former, and they should be considered as average hourly wages, the total number of working hours and output/total number of working hours in the latter cases. In the former case, the coefficients t_3, t_4 could be larger if the labour regulations are weak.

Employers could respond to higher minimum wages by increasing the working hours of formal workers and discard overtime payments, which increases output per worker without additional labour costs. Indeed, Ye, Gindling and Li (2015) find that increase in monthly minimum wages in 6 provinces in China also increased hours worked for unskilled manual workers and workers in small firms, although 29% of overtime workers do not receive any overtime payments. Gürcühan Yüncüler and Yüncüler (2016) estimate that the monthly minimum wage hike in 2004 in Turkey increased hours worked per worker in the formal sector and Pratomo (2013) finds that rising monthly minimum wages increase hours worked for female and male workers in urban and male workers in Indonesia.

Nominal formal and informal wages are positive functions of nominal minimum wages (W_{Mt}) as higher minimum wages would have a direct effect on the formal wages and also improve the bargaining position of both types of workers.

$$W_{Ft} = W_{Ft}(W_{Mt}, \frac{Y_t}{T_t}), \quad W_{(Ft)1} > 0, \quad W_{(Ft)2} > 0 \quad (6)$$

$$W_{It} = W_{It}(W_{Mt}, \frac{Y_t}{T_t}), \quad W_{(It)1} > 0, \quad W_{(It)2} > 0 \quad (7)$$

where average formal wages are higher than average informal wages ($W_{Ft} > W_{It}$).

In the model, nominal unit labour costs for formal and informal workers increase prices by increasing overall unit costs. Nominal wages for formal and informal divided by labour productivity are proxies for nominal unit labour costs for formal and informal workers, respectively. Higher capacity utilisation (Y_t/K_t) also leads to higher prices as below:

$$P_t = P_t\left(\frac{W_{Ft}}{T_t}, \frac{W_{It}}{T_t}, \frac{Y_t}{K_t}\right), \quad P_{(t)1} > 0, \quad P_{(t)2} > 0, \quad P_{(t)3} > 0 \quad (8)$$

where K_t is the capital stock. The current capital stock is the sum of current investment and capital stock in the previous period discounted for a constant capital depreciation rate (δ_t).

$$K_t = I_t + K_{t-1}(1 - \delta_t) \quad (9)$$

Using equations (6)-(8), I simplify the price equation as below:

$$P_t = P_t(W_{Mt}, Y_t, T_t, K_t), \quad P_{tM} > 0, \quad P_{tY} > 0, \quad P_{tT} < 0 \quad P_{tK} < 0 \quad (10)$$

Higher minimum wages have a direct positive effect on prices through raising unit labour costs ($P_{tM} > 0$), higher aggregate demand raise prices through higher capacity utilisation rates and its positive effects on wages ($P_{tY} > 0$), whereas rising labour productivity would have a negative effect on prices through decreasing unit labour costs ($P_{tT} < 0$) and for constant output higher capital stock would have a negative effect on prices through lowering capacity utilisation rates ($P_{tK} < 0$).

Using equations (5)-(7),(10), I simplify the equations for the wages of formal and informal workers as

$$w_{Ft} = w_{Ft}(W_{Mt}, Y_t, K_t), \quad w_{(Ft)M} > 0, \quad w_{(Ft)K} > 0 \quad (11)$$

$$w_{It} = w_{It}(W_{Mt}, Y_t, K_t), \quad w_{(It)M} > 0, \quad w_{(It)K} > 0 \quad (12)$$

Minimum wages could positively affect real wages by raising nominal formal and informal wages; however, minimum wages' impact on price could counteract this effect. Based on strong evidence on minimum wages' positive effect on wages (Harasztosi and Lindner, 2019; Cengiz et al., 2019; Mansoor and O'Neill, 2021) including the informal wages (Perez, 2020) and wages in lower wage firms (Hau, Haung and Wang, 2020), higher minimum wages are likely to increase real wages for both formal and informal workers ($w_{(Ft)M} > 0 > 0, w_{(It)M} > 0$). A higher capital stock would affect real wages positively through its influence on prices. The impact of aggregate demand on real wages is ambiguous, as it could positively affect real wages through employment and negatively affect real wages through prices.

The formal (E_{Ft}) and informal (E_{It}) employment are

$$E_t^F = E_t \sigma_t = \frac{Y_t(\sigma_t)}{T_t} \quad (13)$$

$$E_t^I = E_t(1 - \sigma_t) = \frac{Y_t(1 - \sigma_t)}{T_t} \quad (14)$$

where σ_t is the share of formal employment in total employment.

$$\sigma_t = \sigma_t(W_{Mt}), \quad \sigma_t' < 0 \quad (15)$$

Based on the empirical evidence on developing economies (Broeckea, Fortia and Vandeweyer, 2017), the model considers that higher minimum wages can increase the share of informal employment.

In the model, the capitalists receive profits and the profit share in total income (π_t) is below³:

³For simplicity, the model doesn't consider self-employed, which constitutes a significant share of informal

$$\pi_t = \frac{Y_t - w_{Ft}E_t^F - w_{It}E_t^I}{Y_t} = 1 - \frac{w_{Ft}Y_t\sigma_t}{T_t} - \frac{w_{It}Y_t(1 - \sigma_t)}{T_t} \quad (16)$$

The consumption function can be defined as the sum of the consumption of formal and informal workers and capitalists.

$$\begin{aligned} C_t &= c_0 + c_F w_{Ft} E_t^F + c_I w_{It} E_t^I + c_R Y_t \pi_t \\ &= c_0 + c_F \frac{w_{Ft} Y_t \sigma_t}{T_t} + c_I \frac{w_{It} Y_t (1 - \sigma_t)}{T_t} + c_R Y_t \pi_t \end{aligned} \quad (17)$$

Following Keynes(1936) and the solid and consistent empirical evidence that supports Keynes (Fisher et al., 2020; Onaran and Galanis, 2014; Hein and Vogel, 2008; Alarco, 2016; Onaran, Oyvat and Fotopoulou; 2022b), the model considers that individuals with higher incomes have a lower marginal propensity to consume(MPC). Hence, MPC is the lowest for the capitalists and the highest for the workers($c_I > c_F > c_R$).

The investment function is below:

$$I_t = i_0 \left(\frac{Y_t}{K_t} \right)^{i_1} (\pi_t)^{i_2} (b_t)^{i_3}, \quad i_0, i_1, i_3 > 0 \quad (18)$$

where b_t is an exogenous term measuring business confidence. Higher business confidence stimulates investment. Higher capacity utilisation(Y_t/K_t) also creates incentives for investment. According to Bhaduri and Marglin(1990) model, higher profit shares have a direct negative effect on investments⁴. Although higher profit shares could create incentives for investments, declining profit shares through rising wages could also push investments in labour-saving technologies. Indeed, empirical evidence on the impact of profit share is not consistent. Although many estimations find that higher profit share has a direct positive effect on investments, the direct impact of higher profit share and unit labour cost is significant for many countries(Hein and Vogel, 2008; Onaran and Galanis, 2014; c) and even negative for some countries(Alarco, 2016). Therefore, the sign of i_2 is ambiguous.

The exports and imports equations, respectively, are:

$$X_t = \alpha_0 (Y_t^W)^{\alpha_1} (\pi_t)^{\alpha_2} (\varepsilon_t)^{\alpha_3}, \quad \alpha_0, \alpha_1, \alpha_2, \alpha_3 > 0 \quad (19)$$

$$M_t = \beta_0 (Y_t)^{\beta_1} (\pi_t)^{\beta_2} (\varepsilon_t)^{\beta_3}, \quad \beta_0, \beta_1, \beta_3 > 0, \beta_2 < 0 \quad (20)$$

where Y_t^W is the world income and ε_t is the real exchange rate. Higher ε_t shows real exchange employment. However, considering that the informal sector is usually subordinated to the formal sector (Castells and Portes, 1989; Chen, 2006), the capitalists could still extract profits out of informal activities using their monopsonic position. Hence, the informal wages in the model could also include incomes of self-employed and unpaid family workers and part of the profits could be considered as profits from the exploitative relationship between self-employed and capitalists

⁴In Bhaduri and Marglin(1990) model, higher profit shares could still reduce capital accumulation through its effect on capacity utilisation

rate depreciation, increasing exports and decreasing imports. Higher world income generates demand for exported products and services at home. Lower profits share is a reflection of higher unit labour costs, and therefore decline in profit share reduces(increases) exports(imports) by its influence on international competitiveness ($\alpha_2 > 0, \beta_2 < 0$). This assumption is also strongly supported by empirical literature estimating the influence of profit share and unit labour costs on exports and imports(Onaran and Galanis, 2014; Blecker, Cauvel and Kim, 2022; Onaran, Oyvat and Fotopoulou; 2022b) for various countries.

3.2 The short-run effect of minimum wages on aggregate demand

The contemporaneous effect of an increase in minimum wages on aggregate demand is

$$\theta_{tt} = \frac{dY_t}{dW_{Mt}} = \frac{\left| \frac{\partial C_t}{\partial W_{Mt}} \right|_{Y_t} + \left| \frac{\partial I_t}{\partial W_{Mt}} \right|_{Y_t} + \left| \frac{\partial X_t}{\partial W_{Mt}} \right|_{Y_t} - \left| \frac{\partial M_t}{\partial W_{Mt}} \right|_{Y_t}}{(1 - \psi_t)} \quad (21)$$

where

$$\psi_t = \frac{dC_t}{dY_t} + \frac{dI_t}{dY_t} + \frac{dX_t}{dY_t} - \frac{dM_t}{dY_t} \quad (22)$$

and $1/(1 - \psi_t)$ is the multiplier. The model assumes that it satisfies the Keynesian stability condition and hence $1/(1 - \psi_t) > 0$. Appendix 1 presents the terms of the multiplier in detail.

For constant aggregate incomes, an increase in minimum wages would affect labour productivity positively as below:

$$\left| \frac{\partial T_t}{\partial W_{Mt}} \right|_{Y_t} = T_t \left(t_3 \frac{w_{(Ft)M}}{w_{Ft}} + t_5 \frac{w_{(It)M}}{w_{It}} \right) > 0 \quad (23)$$

Rising minimum wages would influence the profit share through three channels in the short run, as in equation (24). Higher minimum wages have a direct negative impact on the profit share through increasing wage costs; however, this effect could become weaker if higher minimum wages also lead to a growing share of informal workers. For constant aggregate output, increasing minimum wages would also increase labour productivity, alleviating a possible profit squeeze.

$$\begin{aligned} \left| \frac{\partial \pi_t}{\partial W_{Mt}} \right|_{Y_t} &= -Y_t \left(\frac{w_{(Ft)M}\sigma_t + w_{(It)M}(1 - \sigma_t)}{T_t} \right) - \frac{\sigma'_t Y_t (w_{Ft} - w_{It})}{T_t} \\ &\quad + \left| \frac{\partial T_t}{\partial W_{Mt}} \right|_{Y_t} \frac{Y_t (w_{Ft}\sigma_t + w_{It}(1 - \sigma_t))}{T_t^2} > 0 \end{aligned} \quad (24)$$

Overall $\left| \frac{\partial \pi_t}{\partial W_{Mt}} \right|_{Y_t}$ is likely to be positive if the wage elasticity of labour demand is above -1, which is a likely assumption at least for the short run.

For constant aggregate demand, rising minimum wages increase consumption through rising total formal and informal wage payments; however, this effect could be reduced by rising

informality and labour productivity (and hence employment)⁵. Higher minimum wages would have a negative effect on consumption by reducing overall profits.

$$\left| \frac{\partial C_t}{\partial W_{Mt}} \right|_{Y_t} = Y_t \left(\frac{c_F w_{(Ft)M} \sigma_t + c_I w_{(It)M} (1 - \sigma_t)}{T_t} + \frac{\sigma'_t (c_F w_{Ft} - c_I w_{It})}{T_t} - \sigma_t \left| \frac{\partial T_t}{\partial W_{Mt}} \right|_{Y_t} \left(\frac{w_{Ft} \sigma_t + w_{It} (1 - \sigma_t)}{T_t^2} \right) + c_R \left| \frac{\partial \pi_t}{\partial W_{Mt}} \right|_{Y_t} \right) \quad (25)$$

Following the Post-Kaleckian literature (Oyvat, Oztunalı, and Elgin, 2020; Onaran and Galanis, 2014; Hein and Vogel, 2008; Alarco, 2016; Onaran, Oyvat and Fotopoulou; 2022b) that strongly show the positive effects of rising wage shares on consumption and Aaronson, Agarwal and French(2012) and Alonso(2022)'s estimations find that minimum wages' positive impact on consumption; we can consider that higher minimum wages boost consumption. The impact of higher minimum wages on investments is ambiguous and depends on the profit share's effect on investment, as in equation (26).

$$\left| \frac{\partial I_t}{\partial W_{Mt}} \right|_{Y_t} = i_2 \left| \frac{\partial \pi_t}{\partial W_{Mt}} \right|_{Y_t} \frac{I_t}{\pi_t} \quad (26)$$

For constant aggregate demand, the impact of higher minimum wages on exports and imports is negative and positive in the short run due to rising unit labour costs.

$$\left| \frac{\partial X_t}{\partial W_{Mt}} \right|_{Y_t} = \alpha_2 \left| \frac{\partial \pi_t}{\partial W_{Mt}} \right|_{Y_t} \frac{X_t}{\pi_t} < 0 \quad (27)$$

$$\left| \frac{\partial M_t}{\partial W_{Mt}} \right|_{Y_t} = \beta_2 \left| \frac{\partial \pi_t}{\partial W_{Mt}} \right|_{Y_t} \frac{M_t}{\pi_t} > 0 \quad (28)$$

In summary, for constant aggregate demand, an increase minimum wages is respectively likely to increase and reduce aggregate demand through consumption and net exports. The impact of minimum wages on investments is ambiguous. Rising minimum wages have an additional effect on the components of GDP and overall aggregate demand through the multiplier effect. If the impact of minimum wages on demand is positive(negative), then the demand regime in this economy is *minimum wage-led(minimum wage-burdened)*.

3.3 The short-run effect of minimum wages on productivity, employment and prices

The minimum wages would affect labour productivity as in equation (29)

$$\frac{dT_t}{dW_{Mt}} = \left| \frac{\partial T_t}{\partial W_{Mt}} \right|_{Y_t} + t_1 \frac{T_t}{Y_t} \theta_{tt} \quad (29)$$

⁵ $(c_F w_{Ft} - c_I w_{It}) > 0$ is a valid assumption since a decline in the wage of a formal worker due to switching to informal employment affects the worker's consumption negatively.

The first term is minimum wage's direct positive effect on labour productivity. However, as the second term shows, minimum wage also could have an indirect effect on labour productivity through a rising/declining scale depending on whether the demand regime is minimum wage-led or minimum wage-burdened. Similar to Naastepad(2006), who names the productivity regimes as wage-led/profit-led, I label the regimes in which higher minimum wages increase and decrease labour productivity, respectively, as *minimum wage-led* and *minimum wage-burdened productivity* regimes.

Equation (30) shows the effect of minimum wages on total employment. As the first term shows, higher minimum wages could stimulate aggregate demand and generate additional employment in minimum wage-led demand regimes. The second term reflects the minimum wage effect through productivity.

$$\frac{dE_t}{dW_{Mt}} = \frac{1}{T_t} \left(\theta_{tt} - \frac{dT_t}{dW_{Mt}} \frac{Y_t}{T_t} \right) \quad (30)$$

In the cases in which minimum wages are determined as monthly wages, and there are weaker regulations on working hours, the companies could respond to minimum wage hikes by increasing the working hours of full-time workers. In this case, minimum wage hikes would have a stronger effect on labour productivity (measured as output/worker), which would make the impact of minimum wages on employment more negative or less positive.

Table 1 summarises the outcomes of a minimum wage shock on employment based on different demand and productivity regimes. Higher minimum wages reduce employment in the case of minimum wage-burdened demand and minimum wage-led productivity. In the cases of minimum wage-led demand/minimum wage-led productivity and minimum wage-burdened demand/minimum wage-burdened productivity, minimum wage's effect on employment is ambiguous. It is dependent on the size of the effects through demand and productivity. Minimum wage-led demand/minimum wage-burdened regime is not possible as higher minimum wages cannot reduce labour productivity if it positively affects demand, as in equation (29).

As in equation (31), minimum wages influence prices through three channels in the short run: i) Direct positive effect through rising unit labour costs. ii) Positive(negative) effect through rising(declining) capacity utilisation depending on whether the demand regime is minimum wage-led(minimum wage-burdened). iii) Negative(positive) effect through rising(declining) labour productivity depending on whether the productivity regime is minimum wage-led(minimum wage-burdened).

$$\frac{dP_t}{dW_{Mt}} = P_{tM} + \theta_{tt}P_{tY} + \frac{dT_t}{dW_{Mt}}P_{tT} \quad (31)$$

The greater size of θ_{tt} and smaller size of $\frac{dT_t}{dW_{Mt}}$ would make the impact of minimum wage hikes on employment and prices respectively more positive(or less negative) and more negative(or less positive). Therefore, the cases in which minimum wage hikes have a worse effect on employment are less likely to suffer from its impact on inflation.

Table 1: Impact of minimum wages on employment in different demand and productivity regimes (“+”=positive effect on employment, “-” =negative effect on employment)

	Minimum wage-led demand	Minimum wage-burdened demand
Minimum wage-led productivity	(+/-)	(-)
Minimum wage-burdened productivity	∅	(+/-)

$$\frac{dP_t}{dW_{Mt}} = P_{tM} + \theta_{tt}(P_{tY} + \frac{T_t}{Y_t}P_{tT}) - P_{tT}\frac{T_t^2}{Y_t}\frac{dE_t}{dW_{Mt}} \quad (32)$$

3.4 Trade openness and formality

This section examines the role of trade openness and informality on the relationship between minimum wages. Several earlier studies (Cassetti, 2012; Rezai; 2015; von Arnim, Tavani, and Carvalho, 2014; Oyvatt, Oztunalı, and Elgin, 2020) examined the impact of trade openness on wage-ledness and conclude that higher trade openness could make an economy more profit-led(or less wage-led) under certain conditions. This paper specifically focuses how trade openness changes the impact of minimum wages.

In equations (19) and (20), exports and imports are respectively functions of positive terms α_0 and β_0 . Both of these terms are positively affected by λ_t , which reflects the structural and institutional factors (e.g. trade agreements) that influence trade openness.

$$\alpha_0 = a_0\lambda_t \quad (33)$$

$$\beta_0 = b_0\lambda_t \quad (34)$$

where $a_0, b_0, \lambda_t > 0$

Following this, the short-run impact of rising trade through an exogenous change in structural and institutional factors is

$$\frac{d\theta_{tt}}{d\lambda_t} = \frac{1}{(1 - \psi_t)} \left(\alpha_2 \frac{X_t}{\alpha_0} \frac{d\chi_t}{dW_{Mt}} + \beta_2 \frac{M_t}{\beta_0} \frac{d\mu_t}{dW_{Mt}} \right) + \frac{d\theta_{tt}}{dY_t} \frac{dY_t}{d\lambda_t} \quad (35)$$

where

$$\chi_t = \left| \frac{\partial X_t}{\partial W_{Mt}} \right|_{Y_t} < 0, \quad \mu_t = \left| \frac{\partial M_t}{\partial W_{Mt}} \right|_{Y_t} > 0 \quad (36)$$

The first term shows that greater trade openness makes the impact of minimum wages on aggregate demand in the short run less positive or more negative by expanding the contribution of net exports, which minimum wages are likely to have a negative effect. The second term

reflects minimum wages' impact through i) rising aggregate demand's effect on the relationship between aggregate demand and minimum wage ii) rising trade openness's effect on aggregate demand.

If higher minimum wages don't significantly change the relationship between aggregate demand and minimum wage and rising trade openness doesn't have sufficiently strong effects on aggregate demand, higher trade openness will make the impact of minimum wages on aggregate demand more negative(or less positive). Trade openness also certainly worsens the impact of minimum wages on aggregate demand in countries with a trade deficit(surplus), and higher aggregate demand makes the impact of minimum wages on aggregate demand more positive(negative).

Higher minimum wages could lead to a decline in formal employment ($\sigma'_t < 0$) in developing economies with weaker institutional structures on monitoring formality. However, this would be a minor problem in advanced economies with smaller informality. The impact of minimum wages on formality could also influence the relationship between minimum wage and aggregate demand, which equation (36) shows.

$$\frac{d\theta_{tt}}{d\sigma'_t} = \left(\frac{Y_t}{1 - \psi_t} \right) \left(\frac{(c_F - c_R)w_{Ft} - (c_I - c_R)w_{It}}{T_t} - \left(i_2 \frac{I_t}{\pi_t} + \alpha_2 \frac{X_t}{\pi_t} - \beta_2 \frac{M_t}{\pi_t} \right) \frac{(w_{Ft} - w_{It})}{T_t} \right) \quad (37)$$

A stronger link between minimum wages and informality weakens minimum wages' influence on profit share and alleviates the short-run adverse effects of minimum wages on net exports. It can also ease the short-run direct negative (or positive) effect (excluding the effect through Y_t) of minimum wages if minimum wages have a direct negative(positive) effect on investments. On the other hand, higher informality could worsen the effect of minimum wages on aggregate demand by reducing its positive effects on consumption.

3.5 The medium-run effect of minimum wages on aggregate demand

This section examines the medium-run impact of a higher minimum wage in the next period. The short-run effects of a minimum wage hike would also persist in the next period. In addition to its short-run effect, higher minimum wages would have an additional impact on the aggregate demand as below:

$$\theta_{t(t-1)} = \frac{dY_t}{dW_{M(t-1)}} = \frac{\left| \frac{\partial C_t}{\partial W_{M(t-1)}} \right|_{Y_t} + \left| \frac{\partial I_t}{\partial W_{M(t-1)}} \right|_{Y_t} + \left| \frac{\partial X_t}{\partial W_{M(t-1)}} \right|_{Y_t} - \left| \frac{\partial M_t}{\partial W_{M(t-1)}} \right|_{Y_t}}{(1 - \psi_t)} \quad (38)$$

The medium-run relationship between minimum wage and aggregate demand highly depends on minimum wage's medium-run impact on labour productivity. The impact of minimum wage

on labour productivity in the next period is

$$\left| \frac{\partial T_t}{\partial W_{M(t-1)}} \right|_{Y_t} = T_t \left(t_2 \theta_{(t-1)(t-1)} \frac{1}{Y_{t-1}} + t_3 \left| \frac{\partial w_{Ft}}{\partial W_{M(t-1)}} \right|_{Y_t} \frac{1}{w_{Ft}} + t_4 \frac{dw_{F(t-1)}}{dW_{F(t-1)}} + t_5 \left| \frac{\partial w_{It}}{\partial W_{M(t-1)}} \right|_{Y_t} \frac{1}{w_{It}} + t_6 \frac{dw_{I(t-1)}}{dW_{I(t-1)}} \right) \quad (39)$$

where $\theta_{(t-1)(t-1)}$ is the impact of minimum wages on the aggregate demand in the previous period as below.

$$\theta_{(t-1)(t-1)} = \frac{dY_{t-1}}{dW_{M(t-1)}} \quad (40)$$

The medium-run effect of higher minimum wages is only through capital stock for constant current aggregate demand.

$$\left| \frac{\partial w_{Ft}}{\partial W_{M(t-1)}} \right|_{Y_t} = w_{(Ft)K} \left| \frac{\partial K_t}{\partial W_{M(t-1)}} \right|_{Y_t} = w_{(Ft)K} \frac{dI_{t-1}}{dw_{M(t-1)}} \quad (41)$$

$$\left| \frac{\partial w_{It}}{\partial W_{M(t-1)}} \right|_{Y_t} = w_{(It)K} \left| \frac{\partial K_t}{\partial W_{M(t-1)}} \right|_{Y_t} = w_{(It)K} \frac{dI_{t-1}}{dw_{M(t-1)}} \quad (42)$$

The impact of minimum wages on the formal and informal wages in the previous period is through its direct positive effect and its effect through aggregate demand.

$$\frac{dw_{F(t-1)}}{dW_{M(t-1)}} = w_{F(t-1)M} + w_{F(t-1)Y} \theta_{(t-1)(t-1)} \quad (43)$$

$$\frac{dw_{I(t-1)}}{dW_{M(t-1)}} = w_{I(t-1)M} + w_{I(t-1)Y} \theta_{(t-1)(t-1)} \quad (44)$$

where $w_{F(t-1)M}$, $w_{F(t-1)Y}$, $w_{I(t-1)M}$ and $+w_{I(t-1)Y}$ are the partial effects (as in equations (11) and (12)) in the previous period.

A minimum wage hike would boost labour productivity further in the next period by switching to labour-saving technologies, as shown in the third and the fifth terms inside the parenthesis in the equation (38). Moreover, a higher minimum wage would have additional effects through current real formal and informal wages, as in the second and the fourth terms. This is because a higher minimum wage would affect prices in the next period through its effects on investments, and hence current capital stock, in the previous period. Last, if the demand regime is minimum wage-led (minimum wage-burdened) in the short run, a minimum wage hike would have further positive (negative) effects on labour productivity in the next period, as shown by the first term inside the parenthesis.

The medium-run effect of minimum wages on profit share is dependent on its effects on real formal and informal wages and labour productivity as below:

$$\left| \frac{\partial \pi_t}{\partial W_{M(t-1)}} \right|_{Y_t} = \frac{Y_t}{T_t^2} \left(-\sigma_t \left| \frac{\partial w_{Ft}}{\partial W_{M(t-1)}} \right|_{Y_t} - (1 - \sigma_t) \left| \frac{\partial w_{It}}{\partial W_{M(t-1)}} \right|_{Y_t} + \left| \frac{\partial T_t}{\partial W_{M(t-1)}} \right|_{Y_t} (w_{Ft}\sigma_t + w_{It}(1 - \sigma_t)) \right) \quad (45)$$

If minimum wages have a contemporaneous negative effect on investment (and hence on capital stock), it will affect prices positively, reducing the real informal and formal wages. In this case, the profit squeeze due to the minimum wage hike would be eased if $\left| \frac{\partial \pi_t}{\partial W_{M(t-1)}} \right|_{Y_t}$ is also positive. However, if minimum wages have a contemporaneous positive effect on investment, this would generate a further positive effect on the real wages in the medium run, and the medium-run effect of minimum wages on profit share becomes ambiguous.

The medium-run impact of minimum wages on consumption depends on its influence on real formal and informal wages, labour productivity and profit share as below and is ambiguous.

$$\left| \frac{\partial C_t}{\partial W_{M(t-1)}} \right|_{Y_t} = Y_t \left(\frac{c_F \sigma_t}{T_t^2} \left(\left| \frac{\partial w_{Ft}}{\partial W_{M(t-1)}} \right|_{Y_t} - \left| \frac{\partial T_t}{\partial W_{M(t-1)}} \right|_{Y_t} \right) + \frac{c_I(1 - \sigma_t)}{T_t^2} \left(\left| \frac{\partial w_{It}}{\partial W_{M(t-1)}} \right|_{Y_t} - \left| \frac{\partial T_t}{\partial W_{M(t-1)}} \right|_{Y_t} \right) + c_R Y_t \left| \frac{\partial \pi_t}{\partial W_{M(t-1)}} \right|_{Y_t} \right) \quad (46)$$

For constant current aggregate demand, a minimum wage hike has a medium-run effect on investments through two channels. It affects investments through profit shares, and the sign of this is dependent on the sign of i_2 and minimum wages' medium-run effect on profit share. It could lead to greater(lower) capital stock through its effect on investment in the previous year, which respectively would have a negative(positive) effect on current investment due to the capacity that already expanded more(less) in the previous period.

$$\left| \frac{\partial I_t}{\partial W_{M(t-1)}} \right|_{Y_t} = i_2 \left| \frac{\partial \pi_t}{\partial W_{M(t-1)}} \right|_{Y_t} \frac{I_t}{\pi_t} - i_1 \frac{dI_{(t-1)}}{dW_{M(t-1)}} \frac{I_t}{K_t} \quad (47)$$

For constant current aggregate demand, the medium-run effect of a higher minimum wage on net exports depends on its effect on profit share. If a minimum wage hike has a positive(negative) effect on the profit share, it respectively increases(reduces) and reduces(increases) exports and imports as below.

$$\left| \frac{\partial X_t}{\partial W_{M(t-1)}} \right|_{Y_t} = \alpha_2 \frac{X_t}{\pi_t} \left| \frac{\partial \pi_t}{\partial W_{M(t-1)}} \right|_{Y_t} \quad (48)$$

$$\left| \frac{\partial M_t}{\partial W_{M(t-1)}} \right|_{Y_t} = \beta_2 \frac{M_t}{\pi_t} \left| \frac{\partial \pi_t}{\partial W_{M(t-1)}} \right|_{Y_t} \quad (49)$$

3.6 The medium-run effect of minimum wages on productivity, employment and prices

This section discusses the medium-run effect of minimum wages on productivity, employment and prices. Higher minimum wages influence labour productivity in the medium run through a direct impact and effects through aggregate demand. The labour-saving technologies that minimum wage hikes could boost are expected to play a more significant role in the medium run compared to the short run.

$$\frac{dT_t}{dW_{M(t-1)}} = \left| \frac{\partial T_t}{\partial W_{M(t-1)}} \right|_{Y_t} + t_1 \frac{T_t}{Y_t} \theta_{t(t-1)} \quad (50)$$

Similar to Section 3.3, higher minimum wages influence employment through aggregate demand and labour productivity, and different effects could be observed depending on the demand and productivity regimes, as in Table 1.

$$\frac{dE_t}{dW_{M(t-1)}} = \frac{1}{T_t} \left(\theta_{t(t-1)} - \frac{dT_t}{dW_{M(t-1)}} \frac{Y_t}{T_t} \right) \quad (51)$$

Last, the minimum wages have a positive(negative) effect on prices through aggregate demand if the demand regime is minimum wage-led(wage-burdened) in the medium run. Similarly, minimum wages have a negative(positive) effect on prices through labour productivity if the demand regime is minimum wage-led(wage-burdened). Last, higher minimum wages could have a negative effect on prices in the medium run if they lead to capacity expansion in the previous period.

$$\frac{dP_t}{dW_{M(t-1)}} = P_{tY} \theta_{t(t-1)} + P_{tT} \frac{dT_t}{dW_{M(t-1)}} + \frac{dK_t}{dW_{M(t-1)}} P_{tK} \quad (52)$$

4 Conclusion

This paper examines the impact of an increase in minimum wages on aggregate demand, employment, labour production and prices by benefitting from a demand-led economic model. The paper shows that a minimum wage hike could increase consumption, reduce net exports and have an ambiguous effect on investments in the short run. Depending on the size of these effects, a demand regime could be either minimum wage-led or minimum wage-burdened in the short run. Higher minimum wages also have additional effects on consumption, investment and net exports in the medium run. The medium-run effects of minimum wages on the components of demand depend on effects through labour productivity and expansion of capital stock in the previous period and are ambiguous.

Higher minimum wages could influence employment through aggregate demand and labour productivity. Higher minimum wages lead to job losses in the case of minimum wage-burdened demand/minimum wage-led productivity regimes. However, minimum wage's impact on employment could either be positive or negative in countries with minimum wage-led demand/minimum

wage-led productivity and minimum wage-burdened demand/minimum wage-burdened productivity regimes.

Higher minimum wages could lead to inflation through rising unit labour costs; however, the effects on inflation could be eased through its positive effects on labour productivity if the productivity regime is minimum wage-led. Higher minimum wages lead to an increase or decline in prices depending on whether higher minimum wages increase or reduce capacity utilisation. If a minimum wage hike contemporaneously boosts investments, the additional expansion of production capacity also negatively affects the prices in the next period.

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Appendix 1

This appendix examines the minimum wage stimulus's income multiplier $1/(1 - \psi_t)$. Higher aggregate demand also influences labour productivity through growing scale (the Verdoorn effect), and its influence through formal and informal wages as below:

$$\frac{dT_t}{dY_t} = T_t \left(t_1 \frac{T_t}{Y_t} + t_3 \frac{w_{(Ft)Y}}{w_{Ft}} + t_5 \frac{w_{(It)Y}}{w_{It}} \right) \quad (\text{A.1})$$

Higher aggregate demand also influences profit share by affecting formal and informal wages and changing labour productivity.

$$\begin{aligned} \frac{d\pi_t}{dY_t} = & \left(- \frac{\sigma_t(w_{Ft} + w_{(Ft)Y}Y_t)}{T_t} - \frac{(1 - \sigma_t)(w_{It} + w_{(It)Y}Y_t)}{T_t} \right. \\ & \left. + Y_t \frac{\partial T_t}{\partial Y_t} \frac{w_{Ft}\sigma_t + w_{It}(1 - \sigma_t)}{T_t^2} \right) \end{aligned} \quad (\text{A.2})$$

An increase in aggregate demand is likely to increase consumption through changes in overall wage payments and profits.

$$\begin{aligned} \frac{dC_t}{dY_t} = & -c_F \frac{\sigma_t(w_{Ft} + w_{(Ft)Y}Y_t)}{T_t^2} - c_I \frac{(1 - \sigma_t)(w_{It} + w_{(It)Y}Y_t)}{T_t^2} \\ & + c_R \left(\pi_t + Y_t \frac{\partial \pi_t}{\partial Y_t} \right) \end{aligned} \quad (\text{A.3})$$

Moreover, an increase in aggregate demand would have a direct positive effect on investments and imports, and it would have additional effects on investment, exports and imports through profit share as below:

$$\frac{dI_t}{dY_t} = I_t \left(i_1 \frac{1}{Y_t} + i_2 \frac{1}{\pi_t} \frac{\partial \pi_t}{\partial Y_t} \right) \quad (\text{A.4})$$

$$\frac{dX_t}{dY_t} = \alpha_2 \frac{X_t}{\pi_t} \frac{\partial \pi_t}{\partial Y_t} \quad (\text{A.5})$$

$$\frac{dM_t}{dY_t} = M_t \left(\beta_1 \frac{1}{Y_t} + \beta_2 \frac{1}{\pi_t} \frac{\partial \pi_t}{\partial Y_t} \right) \quad (\text{A.6})$$