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ARTICLE

Fiscal stimulus in a simple macroeconomic model of monopolistic competition with firm heterogeneity

Cheng-wei Chang[1] · Ching-chong Lai[2,3,4,5] · Ting-wei Lai[3]

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Abstract
This paper studies the impact of a fiscal stimulus by setting up a simple monopolistic competition model with firm heterogeneity in productivity. Several main results are derived from the general equilibrium analysis. First, a rise in firm heterogeneity per se leads to decreases in aggregate output and aggregate consumption, but raises the aggregate price level when the variety-enhancing effect is sufficiently strong. Second, a fiscal expansion will bring about a positive effect on aggregate consumption, provided that the variety-enhancing effect is relatively strong or the extent of firm heterogeneity is relatively small. Finally, a fiscal expansion may raise social welfare, depending on the size of the variety-enhancing effect and the extent of firm heterogeneity.

Keywords Monopolistic competition · Firm heterogeneity · Fiscal policy

JEL Classification E30 · E62 · L11

1 Introduction

An increasing number of cross-country studies show that firm-level heterogeneity in productivity has recently increased.[1] Despite the fact that the productivity spread has been widening, a thorough macroeconomic analysis resulting from this change is

[1] We will have a literature review in Sect. 2.2 for more in-depth discussions on this point.

✉ Cheng-wei Chang
d95323010@ntu.edu.tw

1 Department of Economics, Tunghai University, Taiwan Boulevard, Taichung, Taiwan

2 Institute of Economics, Academia Sinica, Taipei, Taiwan

3 Department of Economics, National Chengchi University, Taipei, Taiwan

4 Institute of Economics, National Sun Yat-Sen University, Kaohsiung, Taiwan

5 Department of Economics, Feng Chia University, Taichung, Taiwan

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somewhat lacking. In particular, the existing literature on the effectiveness of fiscal policy does not fully shed light on the relevance of firm heterogeneity in productivity in this context. Instead, most studies employ a monopolistic competition model featuring that all firms have the same productivity.[2] To this end, the aim of this paper is to fill this gap in the theoretical research. This addition of firm heterogeneity helps reconcile models with a richer set of facts, on the one hand, and, on the other hand, helps facilitate a better understanding of how firms behave differently toward the same policy, further delivering richer implications for government policy, as pointed out by Lucas (1978).

To explore the policy effects, this paper sheds light on the following two distinctive features in our model setup. The first feature is the presence of productivity differences across monopolistically competitive firms à la Melitz (2003). Our work thus departs from most monopolistic competition models characterized by a zero-profit condition along with a symmetric equilibrium across firms. That is, the embedded firm heterogeneity enables us to analyze how an evolved industry structure can influence the effectiveness of a fiscal expansion and the magnitude of crowding-in effects.[3]

The second feature is that government spending on infrastructure is effective in reducing private production costs. It is generally recognized that public infrastructure, such as the development and construction of industrial parks, logistics parks, railways, ports, and water supply as well as public R&D investment, is effective in reducing private production costs since the firm's private investment in these kinds of items is very likely to be replaced by the government's provision. In a related study, Morrison and Schwartz (1996) use state-level data on the manufacturing sector and find that public infrastructure investment can generate cost-saving benefits, thereby raising the productivity growth of firms. Using state-level U.S. manufacturing data, Cohen and Paul (2004) also find that within-state public infrastructure investment has a significantly direct effect in terms of saving manufacturing production costs.

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[2] Ever since the pioneering work of Dixit and Stiglitz (1977), a growing number of studies have focused on macroeconomic policies in the imperfectly competitive goods market, e.g., Dixon (1987), Startz (1989), Molana and Moutos (1992), Dixon and Lawler (1996), Molana and Zhang (2001), Chao and Takayama (1987; 1990), Chen et al. (2005), and Molana et al. (2012), to mention just a few. The principal component of an imperfectly competitive macroeconomic model is that firms have monopoly power in the product market and set prices optimally in light of the market demand. Based on micro-foundations of optimizing behavior, these studies find that the model provides us with greater policy insights than a purely competitive counterpart.

[3] In an interesting article, Mino (2016) builds up an endogenous growth model featuring financial frictions and firm heterogeneity in productivity. In his model, the economy consists of two types of agents: workers and entrepreneurs. The heterogeneity is exhibited in the entrepreneur's behavior. To be more specific, the entrepreneur tends to participate in goods production when its production efficiency is higher than the cutoff, while it is inclined to become a rentier when its production efficiency is lower than the cutoff. Mino (2016) then uses the model to examine how the heterogeneity of the entrepreneur's productivity affects the growth effect of fiscal policies. This paper instead sets up a non-sustained growth model featuring the heterogeneous productivity across monopolistically competitive firms, and then focuses on how the heterogeneity of firm productivity affects the output and welfare effects of fiscal policies.

To our knowledge, analyzing the effect of a fiscal stimulus in the presence of differing firm heterogeneity and associating it with the enhancing effect of product variety are the two most distinctive features of this paper. There are three main results obtained from our analysis. First, we stress that as firm productivity is Pareto distributed, an increase in the extent of firm heterogeneity will depress aggregate output and aggregate consumption, but will stimulate the aggregate price level when there is a sufficiently strong variety-enhancing effect. Second, we show that a rise in government spending results in an ambiguous effect on private consumption. It turns out that the positive effect on private consumption arises when the size of the variety-enhancing effect is relatively strong or the extent of firm heterogeneity is relatively small. Finally, we perform a welfare analysis and assert that a fiscal expansion may raise or reduce welfare, depending on the relative magnitudes of the variety-enhancing effect and the extent of firm heterogeneity as well.

The rest of this paper is organized as follows. Section 2 reviews related literature and relevant empirical observations. Section 3 lays out the theoretical model. Section 4 discusses the steady-state equilibrium. Section 5 analyzes how fiscal policy affects the economy in equilibrium. Section 6 evaluates the welfare effect of the fiscal policy. Section 7 concludes the paper.

2 Related literature and the evidence

2.1 Related literature

We first review the literature in regard to firm heterogeneity. There is a large body of theoretical research related to Melitz (2003), in which he proposes a monopolistic competition model that incorporates firm heterogeneity together with fixed production costs. In a similar vein, Helpman et al. (2004) extends the model with a particular emphasis on the dispersion levels of firm productivity in different industries. Chaney (2008) embeds into the Melitz-type model an assumption that productivity follows a Pareto distribution, providing a simple and tractable way for equilibrium analysis. An excellent and detailed literature review refers to Redding (2011) and Melitz and Redding (2014). This paper extends their canonical framework to discuss the general-equilibrium effect of a fiscal stimulus with theoretical emphasis on firm heterogeneity.

A common feature shared by the vast majority of studies in the literature on the impact of a fiscal stimulus in the monopolistically competitive goods market is that the relevant studies unanimously confine their analysis to the perspective of market structure. In other words, they highlight how the degree of monopoly power will govern the determination of relevant macroeconomic variables. However, there is surprisingly little attention paid to how the effectiveness of macroeconomic policies is related to the industrial structure, which is characterized by the dispersion of production efficiency among firms. Accordingly, we follow Helpman et al. (2004) in modeling the spread of firm heterogeneity and shedding light on distributional parameters. Although our paper is closely related to Helpman et al. (2004) in that we conduct a policy analysis given a different industrial dispersion level, our focus is on the aggregate (macroeconomic) variables rather than firm-level ones. More specifically, this paper provides a systematic analysis, coupled with a simple diagrammatic exposition, that formally addresses the issue of how the determination of relevant macroeconomic variables and the efficacy of macroeconomic policies are related to firm heterogeneity in production efficiency.

As for the variety effect, in their previous study, Devereux et al. (1996) specify a parameter to capture both the returns to production specialization and the degree of monopolistic competition. With such a specification, they show that an increase in government spending can increase consumption when there is a lower elasticity of substitution. By assigning two distinct parameters to reflect the returns to production specialization and the degree of monopoly power, Chang et al. (2018) find that the degree of increasing returns to specialization plays an important role in governing the effects of a fiscal stimulus on private consumption. By building up an expanding-variety endogenous growth model, Bucci (2013) finds that returns to production specialization play an important role in explaining the correlation between product market competition and economic growth. In addition, Pavlov and Weder (2012) and Chang and Lai (2017) consider endogenous entry under monopolistic competition and show that the variety effect plays an important role in governing belief-driven fluctuations. To sum up, this paper departs from the existing literature in two crucial respects. On the one hand, we consider the self-selection effect of heterogeneous firms in production and, on the other, we further show that whether or not a fiscal expansion leads to a crowding-in or crowding-out effect on private consumption is determined by the relative importance of product variety and the extent of firm heterogeneity.

2.2 The evidence

The presence of great heterogeneity in the performance of firms has long been recognized and is viewed as a well-established fact; see, for example, Bartelsman and Doms (2000) and Syverson (2011) for a comprehensive literature survey. More importantly, there is a growing literature suggesting that productivity dispersion among firms has increased in recent years. Using cross-country survey/census data, most of the empirical studies point to the consistent finding. For example, Barth et al. (2016) find that in the U.S., labor productivity at the establishment level, which is measured by revenues per worker, experienced a widened variance in manufacturing and service industries from 1997 to 2007. Faggio et al. (2010) show that the dispersion of firm-level productivity within industries in the U.K. has a clearly upward trend over 1984–2001. Cette et al. (2018) also find a growing productivity dispersion among French firms during the period 1992–2014. In addition, using a dataset for Japanese firms, Ito and Lechevalier (2009) confirm that an increasing dispersion level of labor productivity and TFP arises from 1998 onwards in Japan.

One way of understanding the evolution of the productivity distribution is via observations of the firm or establishment size distribution (Luttmer, 2010). Using data from the Business Dynamics Statistics (BDS) of the U.S. Census Bureau, we present the evolution of the cumulative distribution of firms (in the left panel) and establishments (in the right panel) across the number of employees in Fig. 1. This figure displays a similar pattern in that the dispersion of establishment size experiences a moderate increase during the period 1977–2014. We also notice that the change in the establishment size distribution appears more evident than the firm size distribution.[4] This change emerges because the share of large and small establishments, especially those with more than 10,000 employees, increases proportionally more than that of the medium-sized counterparts. As suggested by Rossi-Hansberg and Wright (2007), the underlying reason that contributes to the rising intensity of small and large establishments and hence a more dispersed size distribution seems to be the ongoing specialization in services. The process takes a much longer time period to form, and hence can be said to not be directly tied to short-run fiscal policies and the other given parameters.

3 The model

We embed an endogenous labor-leisure choice and incorporate a public sector into an otherwise standard monopolistic competition model proposed by Melitz (2003) in which the monopolistically competitive market is comprised of a continuum of heterogeneous firms. In particular, in line with Egger and Falkinger (2006), we specify that government spending on infrastructure has a negative impact on each producing firm's fixed production costs. The economy consists of three types of agents: households, firms, and a government. In this section, we will outline the model environment.

3.1 Households

The economy is populated by a unit measure of identical households. The representative household derives utility from a composite consumption good C and incurs disutility from providing labor services L. The utility function of the representative household can be expressed as

$$U = \ln C - \xi L; \quad \xi > 0, \tag{1}$$

where ξ represents the disutility weight on work. The utility function in Eq. (1) is specified as the linear labor disutility. As documented by Hansen (1985), the linearity of the utility function in hours worked can be justified by the consequence of aggregation in the presence of indivisible labor.

[4] The observation does not seem to contradict the argument put forth in Luttmer (2010) since the objective of interest in his paper is producing firms instead of establishments. Although the terms 'firm' and 'establishment' are sometimes used interchangeably, our model's focus is more closely associated with the definition of establishments. This is because, according to the definition of a firm by the U.S. census, "a firm is a business organization consisting of one or more domestic establishments." Another concern is that the establishments can be geographically separated and have different business scopes and production technologies, being more consistent with the theoretical property in our model.

The composite consumption good takes a standard constant elasticity of substitution (CES) form:

$$C = M^{\gamma - 1/(\sigma-1)}\left[\int_{\omega\in\Omega} c(\omega)^{(\sigma-1)/\sigma}\mathrm{d}\omega\right]^{\sigma/(\sigma-1)};\ \gamma > 0,\ \sigma > 1, \tag{2}$$

where M is the number of varieties of consumption goods, and as we will explain later, γ is a parameter that reflects love of variety. In addition, $c(\omega)$ is the quantity of each variety ω consumed by the household and σ is the elasticity of substitution between any two varieties in the set Ω that contains the mass of available varieties.

One point involving the specification of composite consumption C in Eq. (2) should be clearly stated. If the representative household consumes the same amount across varieties, say, c, then composite consumption is given by $C = M^{\gamma+1}c$. Accordingly, the increase in aggregate consumption is proportionally more than the increase in the number of varieties given that $\gamma > 0$. This feature implies increasing returns to an expansion in variety, which leads to an increase in the utility of the household. This is referred to as the love-of-variety effect. By contrast, in the pioneering work of Melitz (2003), the parameter σ not only represents the elasticity of substitution but also reflects the extent of the love of variety.[5] As a result, a salient feature of the specification in Eq. (2) is that it facilitates a distinction between love of variety and the elasticity of substitution.[6]

The (aggregate) price associated with the composite consumption good is, therefore, given by

$$P = M^{1/(\sigma-1)-\gamma}\left[\int_{\omega\in\Omega} p(\omega)^{1-\sigma}\mathrm{d}\omega\right]^{1/(\sigma-1)}. \tag{3}$$

Let w denote the wage rate, Π be the aggregate profit received from all producing firms (as the owner of all firms), T be the lump-sum tax in terms of the composite good, M_e be the mass of new entrants, and f_e be the fixed entry cost in units of labor. Accordingly, the aggregate entry cost is equal to wM_ef_e. The representative household receives wage income for providing labor services. Besides, the actual amount of distributed profit that the household can receive is the difference between the aggregate profit and the aggregate entry cost (i.e., $\Pi - wM_ef_e$). After paying the lump-sum tax levied by the government, the household distributes the rest of its income derived from wage income and aggregate profit net of aggregate entry costs to consumption. Accordingly, the household's budget constraint is given by

[5] This is because in Melitz (2003), composite consumption is specified as $C = \left[\int_{\omega\in\Omega} c(\omega)^{(\sigma-1)/\sigma}\mathrm{d}\omega\right]^{\sigma/(\sigma-1)}$. Hence, if the household consumes the same quantity of each variety, say, c, composite consumption is $C = M^{\sigma/(\sigma-1)}c$. It is clear that the love-of-variety effect emerges since the condition $\sigma > 1$ is imposed.

[6] Felbermayr and Prat (2011) develop a monopolistic competition model with firm heterogeneity in productivity, in which they make a distinction between love of variety and the elasticity of substitution. However, in their analysis the love-of-variety effect is absent.

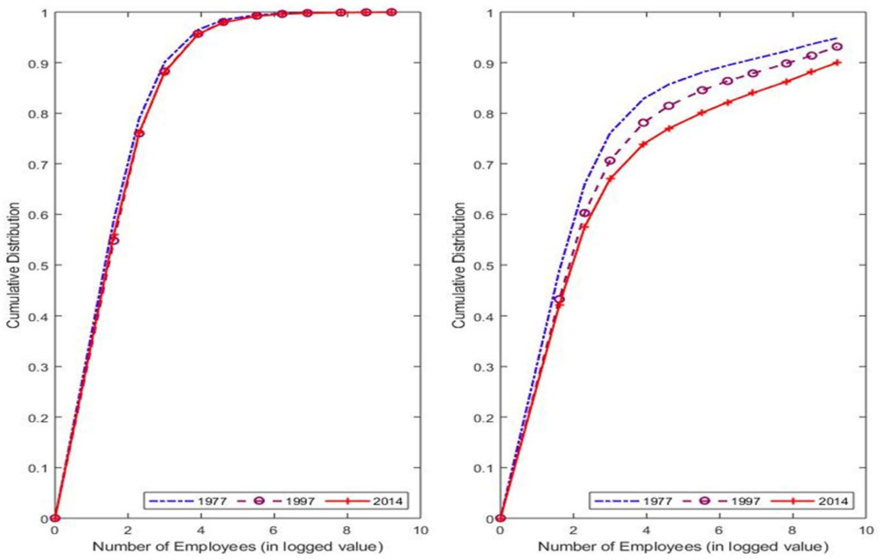


Fig. 1 The distribution of U.S. firms (left) and establishments (right) by size Source: The Business Dynamics Statistics (BDS) of the U.S. Census Bureau

$$wL + (\Pi - wM_e f_e) - PT = PC. \tag{4}$$

Applying a two-stage budgeting decision to the solution of the household's optimization problem yields the following optimum conditions[7]:

$$c(\omega) = (p(\omega)/P)^{-\sigma} M^{\gamma(\sigma-1)-1} C, \tag{5}$$

$$w = \xi PC. \tag{6}$$

Equation (5) denotes the demand for each of the varieties and Eq. (6) states that the household supplies labor by equating the marginal rate of substitution between labor and consumption to the real wage.

3.2 The government

Assume that the government spending composite takes a CES form with the same elasticity of substitution between varieties and the same extent of the love of variety

[7] In the first stage, the representative household chooses composite consumption C and labor supply L to maximize its utility reported in Eq. (1) subject to the budget constraint stated in Eq. (4). In the second stage, the representative household chooses each of the varieties ω to maximize composite consumption C subject to $PC = \int_{\omega \in \Omega} p(\omega)c(\omega)\mathrm{d}\omega$. For a detailed discussion regarding the two-stage budgeting decision, see Heijdra (2017, pp. 369–371).

as in Eq. (2). Since the government makes the optimal expenditure decision in choosing each variety, its demand function can, therefore, be expressed as

$$g(\omega) = (p(\omega)/P)^{-\sigma} M^{\gamma(\sigma-1)-1} G, \tag{7}$$

where $g(\omega)$ is the quantity of each variety ω consumed by the government and G is the amount of government spending on the composite good. Based on Eqs. (5) and (7), we obtain the total demand for each variety as

$$y(\omega) = (p(\omega)/P)^{-\sigma} M^{\gamma(\sigma-1)-1} Y, \tag{8}$$

where $y(\omega) = c(\omega) + g(\omega)$ represents the total demand for each variety ω, and $Y = C + G$ represents the aggregate demand for the composite good.

To fully finance its expenditure, the government levies a lump-sum tax on the household:

$$G = T. \tag{9}$$

3.3 Firms

The economy is composed of a number of active firms and each variety is produced by a single firm. For notational convenience, we hereafter index varieties using firm-level productivity levels $\varphi \in [0, \infty)$.

Following the setting of Melitz (2003), production of each variety requires a fixed production cost and a variable cost, and the variable cost is negatively related to firm's productivity. Additionally, government spending is regarded as an important source that contributes to public infrastructure investment. Following Egger and Falkinger (2006), this infrastructure investment helps reduce each firm's fixed production cost. For simplicity, we assume that the fixed cost is positive but decreasing in government spending, i.e., $f(G) > 0$ and $f'(G) < 0$.[8,9] Accordingly, for the producing firm with productivity φ, total labor needed to produce output $y(\varphi)$ is given by

$$l(\varphi) = f(G) + y(\varphi)/\varphi, \tag{10}$$

where $f(G)$ is a fixed production cost, $l(\varphi)$ is labor demand of the producing firm indexed by φ.

The producing firm with productivity φ sets a pricing rule to maximize its profit π, subject to the market demand in (8) and the production technology in (10). Then

[8] See, for example, Cohen and Paul (2004) and Ezcurra et al. (2005) for empirical evidence regarding this specification.

[9] This paper examines the macroeconomic effects of an exogenous expansion in government spending. As a result, government spending is treated as an exogenous variable rather than an endogenous variable. The exogenous government spending does not allow us to deal with the accumulation of government spending. This is the reason why the fixed cost of production is formulated as a decreasing function of the flow of government spending rather than the stock of the counterpart.

the monopolistically competitive environment results in a pricing rule with a constant markup $\sigma/(\sigma-1)$:

$$p(\varphi) = \sigma w/[(\sigma-1)\varphi]. \tag{11}$$

In line with Melitz (2003), we choose labor as the numéraire, and hence in what follows the wage rate of labor is normalized to unity, i.e., $w = 1$. Equipped with Eqs. (10) and (11) along with $w = 1$, the firm's profit can then be expressed as

$$\pi(\varphi) = p(\varphi)y(\varphi) - wl(\varphi) = y(\varphi)/[(\sigma-1)\varphi] - f(G). \tag{12}$$

Equation (12) indicates that the producing firm can obtain a higher profit when a fiscal stimulus reduces its fixed production cost.

3.4 Aggregation

The goods market is characterized by a mass M of producing firms (and hence M varieties) and the corresponding distribution $\mu(\varphi)$ of productivity levels over the support interval $[0, \infty)$. Accordingly, the aggregate price level is given by

$$P = M^{1/(\sigma-1)-\gamma}\left[\int_0^\infty p(\varphi)^{1-\sigma} M\mu(\varphi)\mathrm{d}\varphi\right]^{1/(1-\sigma)}. \tag{13}$$

Plugging Eq. (11) into (13), we can rewrite the aggregate price as $P = M^{-\gamma}p(\widetilde{\varphi})$, where the weighted average of productivity levels across firms is defined by following Melitz (2003) as

$$\widetilde{\varphi} = \left[\int_0^\infty \varphi^{\sigma-1}\mu(\varphi)\mathrm{d}\varphi\right]^{1/(\sigma-1)}. \tag{14}$$

By means of simple manipulations, the aggregation conditions that associate the aggregates (i.e., the aggregate demand for the composite good and the aggregate profit) with the number of firms and the average productivity level can be expressed as

$$Y = M^{\gamma+1}y(\widetilde{\varphi}), \tag{15}$$

$$\Pi = M\pi(\widetilde{\varphi}), \tag{16}$$

where $y(\widetilde{\varphi})$ and $\pi(\widetilde{\varphi})$ represent the output and profit levels of the firm with average productivity.

It is also noteworthy that in Eq. (15), the exponent $\gamma + 1 > 1$ reveals the degree of increasing returns arising from an expansion in variety. Specifically, it turns out that the amount of aggregate output increases proportionally more than the number of varieties. This outcome emerges because of love of variety and is henceforth referred to as the variety-enhancing effect. The feature regarding the increasing returns due to an expansion in variety has been widely discussed in the literature (see, e.g., Melitz 2003; Ghironi and Melitz 2005; Bernard et al. 2007; Redding 2011; Pavlov and Weder 2012; Chatterjee and Cooper 2014; Chang et al. 2018) and its presence is supported by empirical evidence. In particular, Kasahara and Rodrigue (2008) use detailed plant-level Chilean manufacturing panel data from 1979 to 1996 and show that an increase in the use of varieties leads to a rise in the firm's productivity.

3.5 Firm entry and exit

There are a large number of potential entrants that can enter the market by paying a fixed entry cost f_e in units of labor, which is thereafter sunk. Following Chaney (2008), we assume that, upon entry, firms independently draw their productivity φ from a common Pareto distribution.[10] The cumulative density function of the Pareto distribution is given by

$$H(\varphi) = 1 - \left(\varphi_{\min}/\varphi\right)^{\kappa};\ \kappa > \sigma - 1 > 0, \tag{17}$$

where $\varphi_{\min}$ is the minimum of firm productivity and κ is the shape parameter that governs the dispersion of productivity. A lower value of κ thereby implies a higher degree of firm heterogeneity. Note that the positive average productivity imposes the restriction $\kappa > \sigma - 1$.

Assume that firm productivity remains fixed upon entry and that each firm, regardless of its productivity level, is subject to a constant probability δ that a separation shock hits in each period. The exogenous shock will force the operating firms to exit. Accordingly, the value of a firm with the productivity level φ depends on a stream of future profits:

$$v(\varphi) = \max\left\{0, \sum\nolimits_{t=s}^{\infty} (1-\delta)^{t-s}\pi(\varphi)\right\} = \max\{0, \pi(\varphi)/\delta\}. \tag{18}$$

An entrant firm with the productivity φ will be forced to exit and not to produce if the production yields any negative profit, namely $\pi(\varphi) < 0$. The existence of the fixed production cost turns out a threshold level of productivity $\varphi^* > 0$ such that $\pi(\varphi^*) = 0$ holds. The cutoff productivity level is pinned down by a zero cutoff profit (ZCP) condition (i.e., $\pi(\varphi^*) = 0$) with Eqs. (8), (11) and (12). More specifically, it can be expressed as

$$\varphi^* = \sigma^{\sigma/(\sigma-1)} P^{\sigma/(1-\sigma)} Y^{1/(1-\sigma)} (f(G))^{1/(\sigma-1)} \Big/ \left[(\sigma-1) M^{\gamma - 1/(1-\sigma)}\right]. \tag{19}$$

This ZCP condition means that a firm with a productivity below φ^* will exit immediately and not produce. Given the assumption that the exit rate is independent of firm productivity, the ex post distribution of productivity $\mu(\varphi)$ is, therefore, conditional on the probability of successful entry:

[10] Note that productivity differences can be directly obtained by observing firm size (Luttmer 2010). Since the Pareto distribution has been widely used to model the productivity of heterogeneous firms in the macroeconomics and international trade literature (see, e.g., Helpman et al. 2004; Chaney 2008; Luttmer 2007), we conform to this conventional setting. Axtell (2001) also provides empirical evidence that the size distribution of U.S. firms can be well approximated by the Pareto distribution.

$$\mu(\varphi) = \begin{cases} h(\varphi)/[1 - H(\varphi^*)]; & \text{if } \varphi \geq \varphi^* \\ 0; & \text{otherwise} \end{cases}, \tag{20}$$

where $h(\varphi)$ is the probability density function of $H(\varphi)$. In Eq. (20), the ex ante probability that successful entry occurs (i.e., $1 - H(\varphi^*) \equiv p_{\text{in}}$) is truncated below the cut-off productivity φ^*.

With the help of Eqs. (14) and (20), we can solve for the weighted average of firm productivity:

$$\tilde{\varphi} = \kappa^{1/(\sigma-1)}(\kappa - \sigma + 1)^{1/(1-\sigma)}\varphi^*. \tag{21}$$

As a result of some algebraic manipulation, the price, output and profit levels of the firm with average productivity (or the average price, output and profit levels) can in turn be given by

$$p(\tilde{\varphi}) = \sigma/[(\sigma - 1)\,\tilde{\varphi}], \tag{22}$$

$$y(\tilde{\varphi}) = \kappa(\sigma - 1)f(G)\,\tilde{\varphi}/(\kappa - \sigma + 1), \tag{23}$$

$$\pi(\tilde{\varphi}) = [\tilde{\varphi}^{\sigma-1}(\varphi^*)^{1-\sigma} - 1]f(G). \tag{24}$$

By inserting Eq. (21) into (24), the *ZCP* condition, therefore, implies the average profit:

$$\pi(\tilde{\varphi}) = (\sigma - 1)f(G)/(\kappa - \sigma + 1). \tag{25}$$

Define $\tilde{v}$ as the present value of a stream of future profit flows in association with the weighted average productivity level $\tilde{\varphi}$:

$$\tilde{v} = \sum_{t=s}^{\infty}(1 - \delta)^{t-s}\pi(\tilde{\varphi}) = \pi(\tilde{\varphi})/\delta. \tag{26}$$

As mentioned earlier, the forward-looking firm will enter and pay the fixed entry cost $f_{\text{e}} > 0$ in the case of a positive net value. Equipped with $p_{\text{in}} \equiv 1 - H(\varphi^*)$ and $w = 1$, we further define v_{e} as the value of entry net of the sunk cost:

$$v_{\text{e}} = p_{\text{in}}\tilde{v} - f_{\text{e}}. \tag{27}$$

Thus, new firms enter whenever there is a positive net value.

The free-entry (FE) condition guarantees a zero net value of entry, and as a result of Eq. (27), we can derive $v_{\text{e}} = p_{\text{in}}\tilde{v} - f_{\text{e}} = 0$. Given the distributional setup in Eq. (17) and $p_{\text{in}} \equiv 1 - H(\varphi^*)$, the FE condition yields an alternative expression:

$$\pi(\tilde{\varphi}) = \delta f_{\text{e}}\left(\varphi^*/\varphi_{\min}\right)^{\kappa}. \tag{28}$$

Thus, we can explicitly solve for the two key variables using Eqs. (25) and (28): $\pi(\tilde{\varphi})$ and φ^*.

3.6 Market-clearing conditions and aggregation

The goods market-clearing condition is given by

$$Y = C + G. \tag{29}$$

Recall that M_e is the mass of new entrants and f_e is fixed entry cost. Thus, $L_p = M\,l(\tilde{\varphi})$ and $L_e = M_e f_e$ can be, respectively, denote the quantity of aggregate labor used for producing output and paying for the entry costs. The labor market-clearing condition can be expressed as

$$L = L_p + L_e. \tag{30}$$

Following Melitz (2003), we restrict our attention to the steady-state equilibrium, which is characterized by a mass of new entrants M_e and a mass of producing firms M with the productivity level $\varphi \geq \varphi^*$. In the steady-state equilibrium, the mass of successful entrants will exactly replace the mass of existing ones that are hit by the separation shocks, so that the aggregate stability condition holds:

$$[1 - H(\varphi^*)]M_e = \delta M. \tag{31}$$

Given that $L_p = Ml(\tilde{\varphi})$, we can derive that $L_p = PY - \Pi$ by combining Eqs. (10)–(12), (16), and (30). Based on the definition $L_e = M_e f_e$, we obtain a condition that $L_e = \Pi$ by combining Eqs. (16), (27), (28), and (31). This condition suggests that in equilibrium, the aggregate labor costs paid by new entrants will be equal to the aggregate profit earned by all producing firms. By plugging Eqs. (9) and (30) along with the conditions $L_e = \Pi$ and $w = 1$ into Eq. (4), we can rewrite the household's budget constraint as

$$L = PY. \tag{32}$$

Then from Eq. (6) aggregate consumption can be rewritten as

$$C = 1/(\xi P). \tag{33}$$

As noted, using Eqs. (13) and (14), the aggregate price level can be expressed as $P = M^{-\gamma}p(\tilde{\varphi})$, implying that, ceteris paribus, P is monotonically decreasing in M in the presence of the variety-enhancing effect. That is, the larger the mass of producing firms that there is in the economy, the lower the aggregate price level will be. This result confirms the point argued by Bernard et al. (2007).

Combining Eqs. (13) and (15) gives the relationship between the aggregate revenue of all producing firms and the average revenue:

$$PY = Mp\,(\tilde{\varphi})y(\tilde{\varphi}). \tag{34}$$

Finally, the aggregate profit of all producing firms is given by Eq. (16), i.e., $\Pi = M\pi(\tilde{\varphi})$.

4 The steady-state equilibrium

We are now ready to depict the steady-state equilibrium of the economy. The economy is characterized by Eqs. (13), (16), (21), (25), (28), (29) and (31)–(34) from which we solve for ten variables at the steady state; they are $\tilde{\varphi}$, $\pi(\tilde{\varphi})$, φ^*, M_e, C, L, Y, M, P and Π. They can be sorted into two categories: (i) firm-level variables, which include $\tilde{\varphi}$, $\pi(\tilde{\varphi})$ and φ^*; and (ii) aggregate-level variables, which comprise M_e, C, L, Y, M, P and Π. We will now in turn describe how the variables in these two groupings are determined.

First, we will discuss how the firm-level variables ($\tilde{\varphi}$, $\pi(\tilde{\varphi})$ and φ^*) are determined. A graphical presentation will facilitate our interpretation. In the upper panel of Fig. 2, in association with the initial level of fiscal spending G_0 and the initial extent of firm heterogeneity κ_0, the ZCP(G_0, κ_0) curve traces all pairs of $\pi(\tilde{\varphi})$ and φ^* that satisfy the *ZCP* condition stated in Eq. (25). It is straightforward to infer from Eq. (25) that the ZCP(G_0, κ_0) locus is a horizontal line. In addition, in association with the initial extent of firm heterogeneity κ_0, the FE(κ_0) curve depicts all combinations of $\pi(\tilde{\varphi})$ and φ^* that satisfy the FE condition reported in Eq. (28). It is also clear from Eq. (28) that the FE(κ_0) curve is upward-sloping. The ZCP(G_0, κ_0) curve intersects the FE(κ_0) curve at point Q_0, where the initial equilibrium levels of $\pi(\tilde{\varphi})$ and φ^* are, respectively, equal to $\pi_0(\tilde{\varphi})$ and φ_0^*.

Moreover, in the lower panel of Fig. 2, in association with the initial extent of firm heterogeneity κ_0, we sketch the average productivity curve APC(κ_0), which connects all pairs of $\tilde{\varphi}$ and φ^* that satisfy Eq. (21). The APC(κ_0) locus is a straight line with a positive slope that passes through the origin. At point Q_0 on the APC(κ_0) locus, the initial average productivity equals $\tilde{\varphi}_0$, which is associated with the initial cutoff level of productivity φ_0^* determined in the upper panel of Fig. 2. We can, therefore, obtain from Eqs. (22) and (23) that the initial average price and output levels are simply $p(\tilde{\varphi}_0) = \sigma/[(\sigma - 1)\tilde{\varphi}_0]$ and $y(\tilde{\varphi}_0) = \kappa(\sigma - 1)f(G)\tilde{\varphi}_0/(\kappa - \sigma + 1)$ once $\tilde{\varphi}_0$ is determined.

We then discuss the determination of the aggregate-level variables. Substituting Eq. (33) into (29) gives the goods market-clearing condition:

$$Y = 1/(\xi P) + G. \tag{35}$$

In addition, by inserting the expression for M from Eq. (15) into (34), we can alternatively express the relationship between the aggregate revenue of all producing firms and the average revenue as

$$P = p(\tilde{\varphi})y(\tilde{\varphi})^{\gamma/(\gamma+1)} / Y^{\gamma/(\gamma+1)}. \tag{36}$$

As presented in Fig. 3, in association with the initial level of fiscal spending G_0, the GM(G_0) curve traces all combinations of aggregate output Y and the aggregate price P that satisfy the goods market-clearing condition reported in Eq. (35). In addition, in association with the initial average productivity $\tilde{\varphi}_0$, the RR$(\hat{\varphi}_0)$ curve depicts all combinations of Y and P that satisfy the relationship between the aggregate revenue of all producing firms and the average revenue, as reported in Eq. (36). It is obvious that both the GM(G_0) and RR$(\hat{\varphi}_0)$ curves are downward-sloping and the GM(G_0) curve is steeper than the RR($\hat{\varphi}_0$) counterpart.[11] Figure 3 shows that the GM(G_0) curve intersects the RR($\hat{\varphi}_0$) curve at point Q_0, where the initial equilibrium levels of Y_0 and P_0 are simultaneously determined.

Based on Eq. (33), we can solve for aggregate consumption C in equilibrium once P is determined. Graphically, we can plot an iso-aggregate-consumption curve IC in the (P, Y) plane using Eq. (33). It is quite easy to show that the IC curve is flat.[12] In Fig. 3, we plot the IC(C_0) curve that passes through point Q_0 and it corresponds to the initial level of aggregate consumption, namely C_0. By referring to the expression $C = 1/\xi P$ reported in Eq. (33), we can infer that any points located in the area above (below) the IC(C_0) curve are those where the amount of aggregate consumption is less (greater) than the initial level of aggregate consumption C_0.

5 The comparative statics analysis

This section examines how the firm-level and aggregate-level variables react in response to an increase in government spending given a different extent of firm heterogeneity.

5.1 Firm heterogeneity

To better understand the role of firm heterogeneity, let us first elaborate on how a varying extent of firm heterogeneity has an impact on the relevant firm-level and aggregate-level variables.

To reflect the rise in firm heterogeneity in productivity over time in the U.S., we consider a setup in which the Pareto shape parameter κ is reduced. We first deal with how the firm-level variables will react in response to a reduction in κ. In the upper panel of Fig. 4, a decline in κ from κ_0 to κ_1 shifts the ZCP curve upward from ZCP(G_0, κ_0) to ZCP(G_0, κ_1) and also shifts the FE curve downward from FE(κ_0) to FE(κ_1). The new equilibrium is established at point Q_1, where the ZCP(G_0, κ_1) curve intersects the FE(κ_1) curve. As the equilibrium moves from point Q_0 to point Q_1, the cutoff level of productivity rises from φ_0^* to φ_1^* and the average profit also increases from $\pi_0(\tilde{\varphi})$ to $\pi_1(\tilde{\varphi})$.

In the lower panel of Fig. 4, a decline in κ shifts the APC curve upward from APC(κ_0) to APC(κ_1). The new equilibrium occurs at point Q_1 on the APC(κ_1) curve. By comparing point Q_0 on the APC(κ_0) curve with point Q_1 on the APC(κ_1) curve, we see that the average productivity rises from $\tilde{\varphi}_0$ to $\tilde{\varphi}_1$ when κ falls from κ_0 to κ_1.

We then discuss how the aggregate-level variables will respond following a rise in the extent of firm heterogeneity. It can be shown that the effect on the aggregates is crucially related to the magnitude of the variety-enhancing effect γ. As exhibited

[11] The slopes of the GM and RR curves are shown to be $\partial P/\partial Y|_{\mathrm{GM}} = -P/C < 0$ and $\partial P/\partial Y|_{\mathrm{RR}} = -\gamma P/(\gamma + 1)Y < 0$. As a consequence, the slope of the RR curve relative to that of the GM curve is given by $\partial P/\partial Y|_{RR} - \partial P/\partial Y|_{\mathrm{GM}} = [C + (\gamma + 1)G]P/(\gamma + 1)CY > 0$.

[12] The slope of the IC curve is expressed as $\partial P/\partial Y|_{\mathrm{IC}} = 0$.

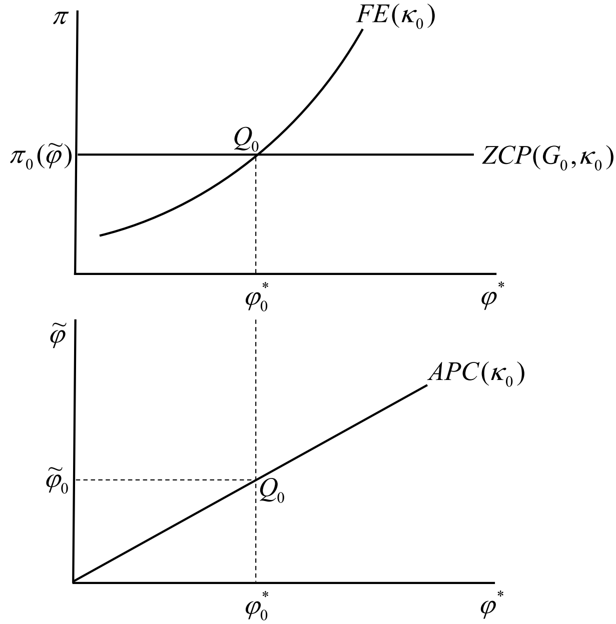


Fig. 2 Determination of the equilibrium $\pi(\tilde{\varphi})$, φ^* and $\tilde{\varphi}$

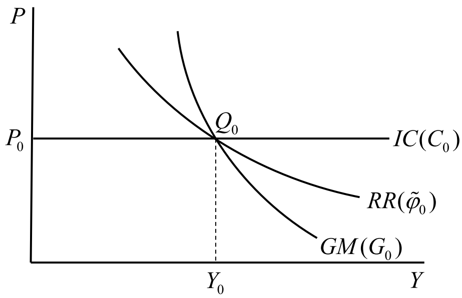


Fig. 3 Determination of the equilibrium Y and P

in the lower panel of Fig. 4, a decline in κ from κ_0 to κ_1 leads to an increase in $\tilde{\varphi}$ from $\tilde{\varphi}_0$ to $\tilde{\varphi}_1$. The upper (lower) panel of Fig. 5 illustrates that a rise in $\tilde{\varphi}$ from $\tilde{\varphi}_0$ to $\tilde{\varphi}_1$ shifts the RR curve rightward (leftward) from RR($\widehat{\varphi}_0$) to RR($\widehat{\varphi}_1$) if the variety-enhancing effect γ is greater (smaller) than a threshold value $\hat{\gamma}$.[13] The new equilibrium occurs at point Q_1 where the GM(G_0) curve intersects the RR($\widehat{\varphi}_1$) curve. As a result, a reduction in κ may give rise to a lower aggregate output level ($Y_1 < Y_0$) and a higher aggregate price level ($P_1 > P_0$) if the variety-enhancing effect is sufficiently strong.

[13] Note that $\hat{\gamma} = 2/(\sigma - 1) + (\kappa - \sigma + 1)\ln\left[(\sigma - 1)f(G)\big/[(\kappa - \sigma + 1)\delta f_e]\right]\big/[(\sigma - 1)\kappa]$.

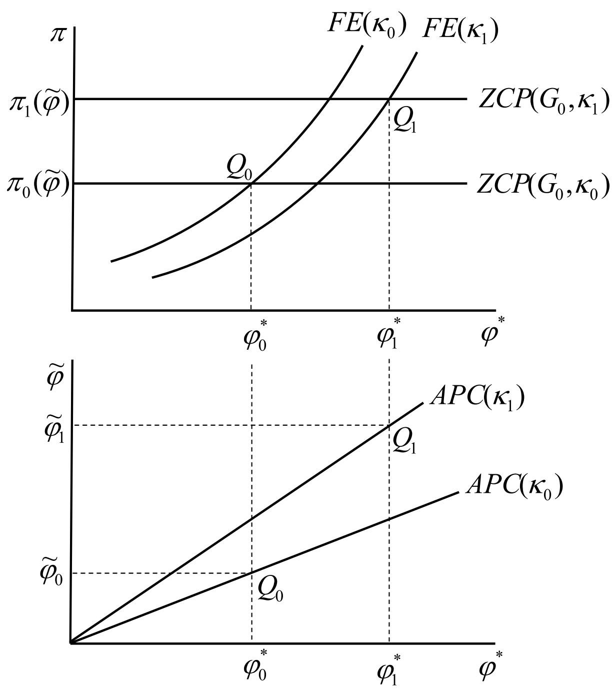


Fig. 4 A rise in firm heterogeneity ($\kappa_0 > \kappa_1$)

The rationale behind these results is straightforward. A decline in κ causes the distribution of the firm's productivity φ to be more dispersed from the minimum level $\varphi_{\min}$, thereby contributing to a rise in the average productivity $\tilde{\varphi}$ (as exhibited in the lower panel of Fig. 4) and further leading to an increase in the average output level $y(\tilde{\varphi})$.[14] With a rise in $y(\tilde{\varphi})$, aggregate output production will increase if the number of firms remains unchanged, resulting in an excess supply in the goods market. Accordingly, to eliminate this excess supply, some firms are forced to exit and the mass of producing firms M decreases. As shown in Eq. (15), the rise in $y(\tilde{\varphi})$ will boost aggregate output Y although the decline in M will reduce Y. Since the latter effect dominates as $\gamma > \hat{\gamma}$, we can conclude that aggregate output Y will decrease in response to a rise in firm heterogeneity.

We can also obtain from Eq. (22) that the average price level $p(\tilde{\varphi})$ falls because of the rise in $\tilde{\varphi}$. Recalling that $P = M^{-\gamma} p(\tilde{\varphi})$ and, therefore, the decline in $p(\tilde{\varphi})$ will drive down the aggregate price P, whereas the decrease in M will raise P. Given that the second effect dominates as $\gamma > \hat{\gamma}$, the economy ends up with an increase in the aggregate price as a result of a rise in firm heterogeneity. With a rise in the aggregate price, as indicated in Eq. (33), aggregate consumption will decline in response.

[14] An extreme case is $\kappa \to \infty$. Under such an extreme case, all firms become homogeneous and have identical productivity, which is equal to the smallest level $\varphi_{\min}$.

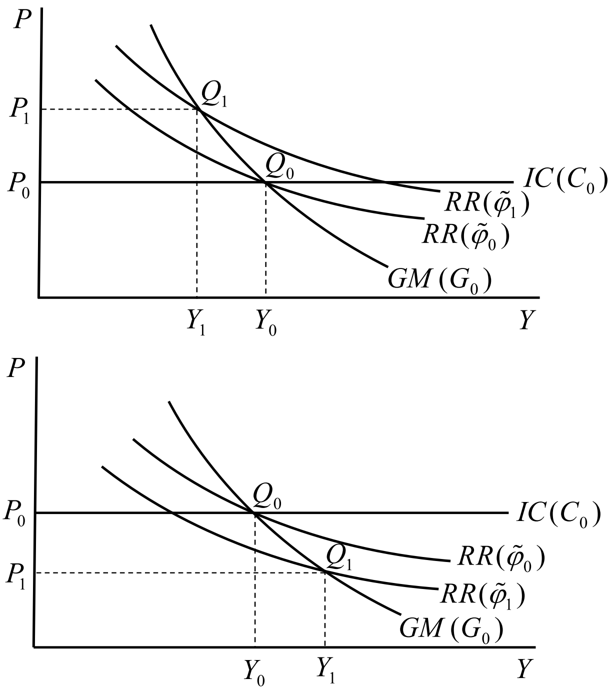


Fig. 5 The effects of a rise in firm heterogeneity ($\kappa_0 > \kappa_1$): $\gamma > \hat{\gamma}$ (upper panel) and $\gamma < \hat{\gamma}$ (lower panel)

"Appendix 1" provides a full derivation regarding the effects of a reduction in κ on the aggregate-level variables.

To gain insights into the firm heterogeneity effect on the aggregate-level variables, we offer a quantitative assessment by applying a numerical analysis. We first assign plausible parameter values to the baseline model and then evaluate the comparative statics in equilibrium. The parameters we set are adopted from commonly used values in the existing literature or are calibrated to match the U.S. data.

As documented by Nardi and Yang (2014) and Occhino and Pescatori (2015), the government spending-to-GDP ratio based on postwar US data is about 0.18, and so we set $\theta = 0.18$. According to Lee (2007) and Chang et al. (2018), the degree of love of variety γ could be as high as 0.6, which is the estimate based on US electrical machinery plants. Thus, the upper bound of γ is 0.6 since it is considered to be the highest possible value from the empirical studies. In view of this fact, the degree of love of variety γ is set to 0.3, which is the average value of the two endpoints [0, 0.6]. In line with Melitz and Redding (2015), the baseline value for the fixed production cost f is normalized to one. Following Melitz and Redding (2015), the baseline value for the entry cost f_e is set to one. The exogenous firm exit rate is set to $\delta = 0.025$, which is adopted by Bernard et al. (2007). As documented by Devereux et al. (1996), the average markup in the U.S. economy is about 1.2. Thus, in line with Monacelli and Perotti (2008), the elasticity of substitution σ is set to 6 (i.e., the price markup is 1.2). As for the extent of firm heterogeneity under the constraint $\kappa > \sigma - 1$, we set its baseline value to 5.6, which is taken from Fattal Jaef and Lopez (2014). The baseline value for the preference parameter ζ is set to 0.01.[15] Accordingly, the aggregate output, aggregate consumption and aggregate price in the steady-state equilibrium are $Y = 175.23$, $C = 143.69$ and $P = 0.7$, respectively.

We are now in a position to explore the effects of a rise in firm heterogeneity on the aggregate-level variables. To this end, Fig. 6 is drawn to confirm that the firm heterogeneity effects hinge on the extent of love of variety γ. It is quite clear from Fig. 6 that, when the variety-enhancing effect is relatively strong (i.e., $\gamma > \hat{\gamma} = 0.52$), the effects of a change in κ on aggregate output, aggregate consumption and the aggregate price exhibit the following results: $\partial Y/\partial \kappa > 0$, $\partial C/\partial \kappa > 0$ and $\partial P/\partial \kappa > 0$. That is to say, under the situation in association with $\gamma > \hat{\gamma} = 0.52$, a rise in firm heterogeneity (which is captured by a decline in κ) leads to decreases in both aggregate output and aggregate consumption, while it leads to an increase in the aggregate price, and vice versa in the opposite case.

Based on the above discussion, we can state the following proposition:

Proposition 1 *Given that the variety-enhancing effect is relatively strong (i.e., $\gamma > \hat{\gamma}$), a rise in firm heterogeneity, which is captured by a decline in κ, leads to decreases in aggregate output and aggregate consumption, while it raises the aggregate price.*

5.2 The fiscal stimulus

In this subsection, we are ready to analyze the effects of a fiscal expansion on the economy-wide variables. We first focus on the determination of the firm-level variables. In the upper panel of Fig. 7, a fiscal expansion leads to a downward shift in the ZCP curve from ZCP(G_0, κ_0) to ZCP(G_1, κ_0). The new equilibrium is established at point Q_1, where the ZCP(G_1, κ_0) curve intersects the FE(κ_0) curve. As the equilibrium moves from point Q_0 to point Q_1, the cutoff level of productivity is reduced from φ_0^* to φ_1^* and the average profit also declines from $\pi_0(\tilde{\varphi})$ to $\pi_1(\tilde{\varphi})$. In addition, the lower panel of Fig. 7 shows that the average productivity declines from $\tilde{\varphi}_0$ to $\tilde{\varphi}_1$ as φ^* falls from φ_0^* to φ_1^*. Based on Eqs. (22) and (23), we can also infer that in response to a fall in $\tilde{\varphi}$, the average output $y(\tilde{\varphi})$ decreases while the average price level $p(\tilde{\varphi})$ rises.

We then turn to the determination of the aggregate-level variables. "Appendix 2" provides a full derivation regarding the analytical comparative statics that shows how a fiscal expansion affects these variables. As shown in "Appendix 2", an expansionary fiscal policy tends to increase the mass of producing firms, while it leads to ambiguous effects on aggregate output, the aggregate price level and private consumption.

[15] Note that a change in ζ does not significantly change the main results of this paper. The results are available from the authors upon request.

Figure 8 delivers a graphical exposition for the above comparative static results. A fiscal expansion from G_0 to G_1 leads to a rightward shift in the GM curve from GM(G_0) to GM(G_1). Moreover, as exhibited in Fig. 7, the average productivity declines from $\tilde{\varphi}_0$ to $\tilde{\varphi}_1$ as G rises from G_0 to G_1, thereby causing the *RR* curve to shift from RR($\hat{\varphi}_0$) to RR($\hat{\varphi}_1$). Figure 8 clearly shows that whether the RR curve moves rightward or leftward depends crucially upon the size of the variety-enhancing effect (γ) and the extent of firm heterogeneity (κ). To be more specific, the RR curve shifts leftward if $\gamma\kappa > 1$(the top panel) or rightward if $\gamma\kappa < 1$ (the middle and bottom panels).[16]

We briefly discuss three scenarios in an attempt to elaborate on how the overall effects on P, Y and C caused by a fiscal expansion hinge on the size of the variety-enhancing effect and the extent of firm heterogeneity. The upper panel of Fig. 8 depicts the first case in which $\gamma\kappa > 1$. In this case, an increase in government spending G from G_0 to G_1 shifts the RR curve leftward from RR($\hat{\varphi}_0$) to RR($\hat{\varphi}_1$). The new equilibrium reaches point Q_1, where the GM(G_1) curve intersects the RR($\hat{\varphi}_1$) curve. As the equilibrium moves from point Q_0 to point Q_1, aggregate output rises from Y_0 to Y_1 and the aggregate price level falls from P_0 to P_1. Moreover, since Q_1 lies in the area below the IC(C_0) curve, it follows that aggregate consumption is greater than the initial level C_0.

Then we consider the case in association with $\varepsilon/(\varepsilon+\theta) < \gamma\kappa < 1$, where $\varepsilon = -f'(G)G/f(G) > 0$ is the elasticity of fixed production cost with respect to government spending and $\theta = G/Y$ is the government spending-output ratio. Different from the previous case, an increase in government spending from G_0 to G_1 shifts the RR curve rightward from RR($\hat{\varphi}_0$) to RR($\hat{\varphi}_1$). Moreover, the rightward shift of the GM curve from GM(G_0) to GM(G_1) is greater than that of the *RR* curve from RR($\hat{\varphi}_0$) to RR($\hat{\varphi}_1$). The middle panel of Fig. 8 shows that the new equilibrium occurs at point Q_1, where the GM(G_1) curve intersects the RR($\hat{\varphi}_1$) curve. As the equilibrium moves to point Q_1, aggregate output rises from Y_0 to Y_1 whereas the aggregate price level drops from P_0 to P_1. Moreover, since Q_1 lies in the area below the IC(C_0) curve, the corresponding aggregate consumption level is greater than the initial level C_0.

Lastly, let us focus on the case where $\gamma\kappa < \varepsilon/(\varepsilon+\theta)$. Given the same increase in government spending from G_0 to G_1, the RR curve in the bottom panel of Fig. 8 shifts rightward from RR($\hat{\varphi}_0$) to RR($\hat{\varphi}_1$). In contrast to the second case, the rightward shift of the GM curve from GM(G_0) to GM(G_1) is smaller than that of the *RR* curve from RR($\hat{\varphi}_0$) to RR($\hat{\varphi}_1$). The new equilibrium thus reaches the intersection of GM(G_1) and RR($\hat{\varphi}_1$), which is indicated by the point Q_1. It turns out that the economy will have a higher aggregate output and a higher aggregate price level.[17] However, aggregate consumption falls below the initial level C_0 since the new equilibrium Q_1 is located in the area above the IC(C_0) curve.

[16] Recall that $\partial Y/\partial G|_{\mathrm{RR}} = (1-\gamma\kappa)\varepsilon/\gamma\kappa\theta \gtrless 0$; if $\gamma\kappa \lesseqgtr 1$.

[17] Under the case where $\gamma\kappa < \varepsilon/(\varepsilon+\theta)$, following a rise in government spending from G_0 to G_1, aggregate output may decrease in response when the upward shift of the GM curve from GM(G_0) to GM(G_1) is smaller than that of the RR curve from RR($\hat{\varphi}_0$) to RR($\hat{\varphi}_1$).

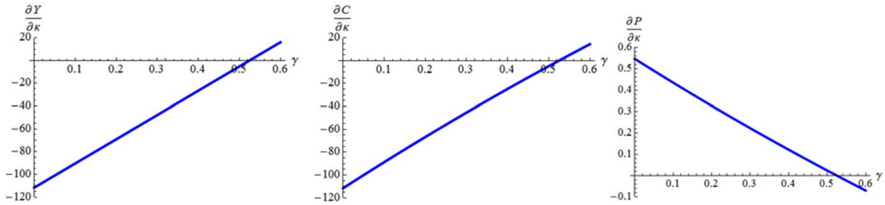


Fig. 6 The macroeconomic effects of firm heterogeneity: the role of love of variety

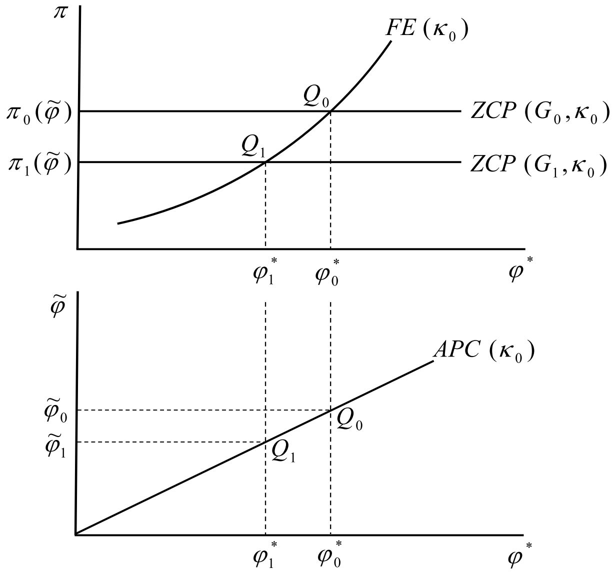


Fig. 7 The effects of a fiscal expansion

Based on the above qualitative analysis, we demonstrate that a fiscal expansion raises aggregate consumption as $\gamma\kappa > \varepsilon/(\varepsilon + \theta)$, shedding light on the crowding-in observations in a number of empirical studies, e.g., Blanchard and Perotti (2002), Fatás and Mihov (2001), Galí et al. (2007), and Monacelli and Perotti (2008). Furthermore, we demonstrate that as $\gamma\kappa > \varepsilon/(\varepsilon + \theta)$, the aggregate price level responds negatively to a fiscal expansion.[18] This provides a plausible interpretation to empirical findings of previous studies such as Fatás and Mihov (2001), Perotti (2004) and Mountford and Uhlig (2009).

The goods market clearing condition (29) and Eq. (57) in "Appendix 2" imply the following comparative static result: $\partial C/\partial G = \partial Y/\partial G - 1 \gtreqless 0$ if $\gamma\kappa \gtreqless \varepsilon/(\varepsilon + \theta)$. This indicates that a fiscal expansion can generate a crowding-in effect on private

[18] Molana and Moutos (1992) develop an imperfectly competitive macroeconomic model, and find that a fiscal expansion leads to an increase in the aggregate price if government spending is financed by lump-sum taxes.

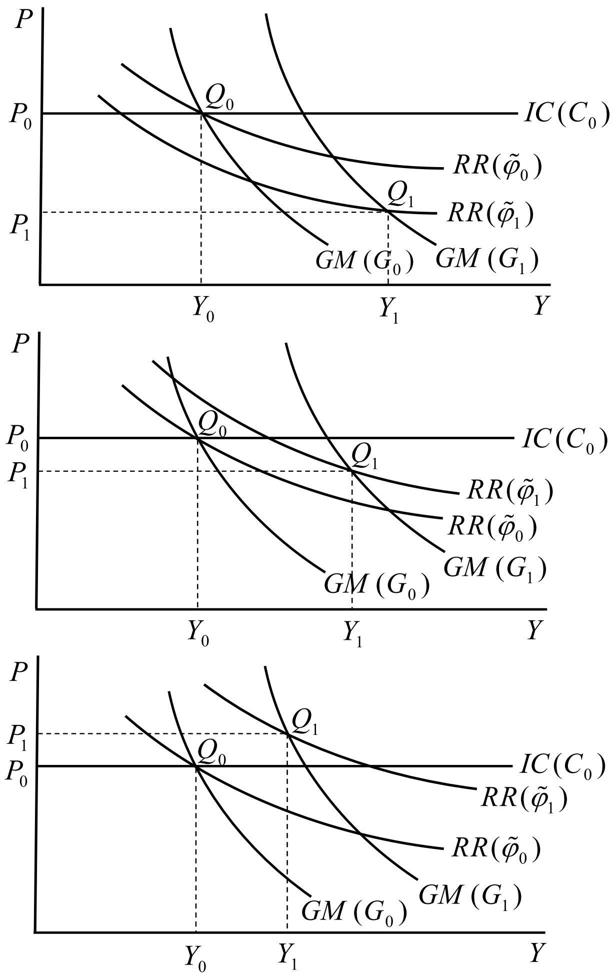


Fig. 8 The effects of a fiscal expansion ($G_1 > G_0$): $\gamma\kappa > 1$ (top panel), $\varepsilon/(\varepsilon + \theta) < \gamma\kappa < 1$ (middle panel) and $\gamma\kappa < \varepsilon/(\varepsilon + \theta)$ (bottom panel)

consumption, if the general equilibrium effect on aggregate output is greater than unity.

To compare the current model with the homogeneous firm model, we consider the limiting case in where $\kappa \to \infty$, i.e., the homogeneous firm scenario. In this case, we find that $\partial C/\partial G \gtreqless 0$; if $\gamma \gtreqless 0$. Accordingly, our limiting case degenerates to the Chang et al. (2018) result, i.e., an increase in government spending generates the crowding-in of private consumption in the presence of increasing returns to an expansion in variety.

Since the policy impact heavily depends on the parameters, to gain insights concerning the plausible values and to see the relevance of firm heterogeneity κ, we offer a quantitative assessment. Following our previous numerical analysis, the government spending-to-GDP ratio θ is set to 0.18, and the degree of love of variety γ is set to 0.3. In addition, using 1982–1996 state-level US manufacturing data to estimate a cost-function model, Cohen and Paul (2004) show that the elasticity of the fixed cost with respect to government spending is about 0.23. This gives $\varepsilon = 0.23$.

Besides, we set the upper bound of κ to 5.6 based on the estimate by Fattal Jaef and Lopez (2014) so that its value ranges from 1 to 5.6, namely $\kappa \in (1, 5.6]$. This parameter interval is sensible since Luttmer (2007) and Luttmer (2010) document that the value can be smaller and is about 1.06. Theoretical studies in the international trade literature by Ghironi and Melitz (2005) and Bernard et al. (2007) set $\kappa = 3.4$, which is within the range of $\kappa \in (1, 5.6]$.

Figure 9 highlights how the extent of firm heterogeneity (κ) governs the effect of fiscal spending on aggregate output. Given that the fiscal crowding-in effect on consumption is consistent with empirical evidence of the US, it is found from Fig. 9 that, to fit the practical evidence, we should impose $\kappa > 1.87$ to satisfy $\partial Y/\partial G > 1$. Moreover, given that the US has been observed to exhibit a rise in firm heterogeneity in productivity (i.e., a lower κ) over past decades, we can, therefore, conclude that a fiscal expansion mitigates its favorable effect on aggregate output in response to a rise in firm heterogeneity in productivity.

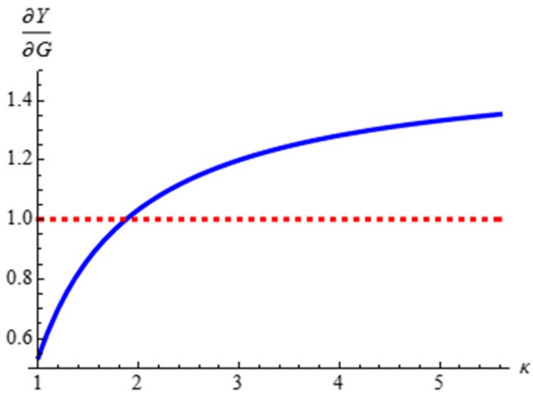
In addition, since the magnitudes of κ and γ play important roles in determining $\partial Y/\partial G$ (and hence $\partial C/\partial G$), so the underlying rationale merits an elaboration. As shown in Eq. (15), we can decompose the effect of a fiscal expansion on aggregate output into two components: (i) a rise in the mass of producing firms M and (ii) a fall in average output $y(\tilde{\varphi})$. The two outcomes emerge in response to a fiscal expansion. On the one hand, a fiscal expansion leads to a rise in the aggregate demand for output. This in turn triggers a self-selection effect causes the entry of less productive firms and hence lowers average productivity and average output $y(\tilde{\varphi})$. On the other hand, a fiscal expansion increases the mass of producing firms M because it can effectively reduce the fixed production cost and also leads to a greater aggregate demand for products from all producing firms. The rise in M and the fall in $y(\tilde{\varphi})$ will, respectively, increase and decrease aggregate output. Overall, the effect on aggregate output depends on the relative size of the two forces and is closely related to the magnitudes of κ and γ.

The comparative statics on aggregate output can help clarify our point. This can be shown analytically as

$$\frac{\partial Y}{\partial G} = \frac{\left[\gamma + 1 + \frac{\varepsilon(1-\theta)(\gamma\kappa-1)}{\theta\kappa}\right]}{\theta(1+\gamma) + 1 - \theta} \gtrless 0; \text{ if } 1 + \left[1 + \frac{\varepsilon(1-\theta)}{\theta}\right]\gamma \gtrless \frac{\varepsilon(1-\theta)}{\kappa\theta}, \tag{37}$$

where the term $[1 + \varepsilon(1-\theta)/\theta]\gamma$ clearly reflects how result (i) is enhanced by the higher variety-enhancing effect (or a higher γ) and the term $\varepsilon(1-\theta)/\kappa\theta$ implies how result (ii) can be lessened if there is a lower extent of firm heterogeneity (or a higher κ). Given that a rise in γ reinforces the favorable effect of M on Y and a rise in κ lessens the unfavorable effect of $y(\tilde{\varphi})$ on Y, a fiscal expansion would be more

Fig. 9 The aggregate output effect of fiscal expansion: the role of firm heterogeneity



likely to result in not only a rise in Y but also a greater increase in Y in association with higher values of γ and κ.[19]

To gain insights into how varying values of γ and κ can drive the effects of fiscal expansion, we conduct another numerical analysis using the same baseline parameterization as in Sects. 5.1 and 5.2. That is, we set $\theta = 0.18$ and $\varepsilon = 0.23$. Similarly, by following Lee (2007) and Chang et al. (2018), the upper bound of γ is set to 0.6 and by following Fattal Jaef and Lopez (2014), the upper bound of κ is set to 5.6.

Guided by these results, in Fig. 10 the range of the parameter γ is set to $\gamma \in [0, 0.6]$ and the range of the parameter κ is set to $\kappa \in (1, 5.6]$. As one can see, the $\gamma - \kappa$ space in Fig. 10 is divided into the two areas. The grey area at upper right displays the region featured by fiscal crowding in (i.e., $\partial C/\partial G > 0$), while the white area at lower left exhibits the region featured by fiscal crowding out (i.e., $\partial C/\partial G < 0$). Apparently, with these plausible values, a higher degree of the love of variety (a higher γ) matched with a lower extent of firm heterogeneity (a higher κ) results in a positive consumption effect, i.e., a fiscal stimulus leads to an increase in consumption.

Based on the above analysis, we can, therefore, conclude that an increase in government spending could generate a fiscal crowding-in effect on private consumption provided that the variety-enhancing effect is stronger (a higher γ) or the extent of firm heterogeneity is smaller (a higher κ).[20] Accordingly, we can formally summarize the result in the following proposition:

Proposition 2 *Afiscal expansion leads to a crowding-in effect on private consumption provided that the variety-enhancing effect is relatively large or the extent of firm heterogeneity is relatively small.*

[19] If we instead specify a constant relative risk aversion function in labor, it is predictable that the intertemporal elasticity of substitution in labor plays a role in determining the effect of a fiscal stimulus on the relevant macroeconomic variables. See Devereux et al. (1996) and Chang et al. (2018) for a more detailed discussion on this point.

[20] The graphical analysis in Fig. 8 and the comparative result in Eq. (57) reveals that $\partial C/\partial G \gtreqless 0$ if $\gamma\kappa \gtreqless \varepsilon/(\varepsilon + \theta)$..

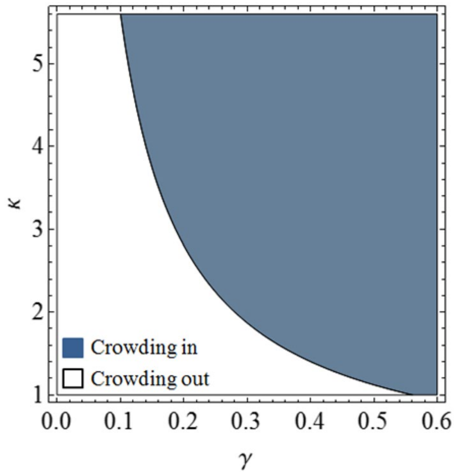


Fig. 10 The fiscal crowding-in and crowding-out regions

6 Welfare analysis

In this section, we assess the effect of an increase in government spending on welfare. This analysis can help us better understand whether an expansionary fiscal policy is desirable in terms of welfare.

By substituting the steady-state equilibrium of C and L into Eq. (1), we can derive the welfare function (i.e., the indirect lifetime utility function).[21] Simple comparative statics suggests that government spending has an ambiguous impact on welfare:

$$\frac{\partial U}{\partial G} = \left[\frac{1}{C}\frac{\partial C}{\partial G} - \xi\frac{\partial L}{\partial G}\right] \gtreqless 0; \text{ if } \gamma[\theta(1-\theta)+\varepsilon] \gtreqless \theta + \frac{\varepsilon}{\kappa}. \tag{38}$$

Note that to determine the sign of the above derivative, the two results reported in "Appendix 2" are required: (i) $\partial C/\partial G \gtreqless 0$ if $\gamma \gtreqless \varepsilon/(\theta+\varepsilon)\kappa$ and (ii) $\partial L/\partial G \lesseqgtr 0$ if $\gamma \gtreqless (\kappa+\varepsilon)/\varepsilon\kappa$.[22]

A further discussion can help to explain all possible outcomes. Specifically, in the case where $\gamma < \varepsilon/(\theta+\varepsilon)\kappa$, the expansionary fiscal policy must cause welfare losses since, as we have argued, private consumption decreases while labor supply increases as responses to the policy.[23] By contrast, the expansionary fiscal policy can generate welfare gains in the other extreme case where $\gamma > (\kappa+\varepsilon)/\varepsilon\kappa$ because private consumption rises and labor supply falls in response to the policy.

[21] In our imperfectly competitive general equilibrium model, as the owner of all producing firms, the representative household receives the profits of all firms in the form of dividends. Accordingly, in line with the literature on imperfect competition, the social welfare is measured by the level of the representative household's utility without resorting to the sum of the consumer's surplus and all firms' profits.

[22] See Eqs. (56) and (57) in Appendix 2 for the details.

[23] It should be noted that $\gamma < (\kappa+\varepsilon)/\varepsilon\kappa$ should be satisfied when $\gamma < \varepsilon/(\theta+\varepsilon)\kappa$. As a result, we have $\partial C/\partial G < 0$ and $\partial L/\partial G > 0$ when $\gamma < \varepsilon/(\theta+\varepsilon)\kappa$.

In considering the other case where two conflicting effects are governed by the magnitudes of the love of variety and firm heterogeneity, we can demonstrate that net welfare gains arise if private consumption increases and the resulting positive effect on welfare offsets losses caused by the increase in labor supply. Put differently, a fiscal expansion will improve the welfare level if the love of variety is sufficiently strong (a higher value of γ) and the extent of firm heterogeneity is sufficiently small (a higher value of κ), namely $\gamma[\theta(1-\theta)+\varepsilon] > \theta + \varepsilon/\kappa$.

An important implication emerges from our welfare analysis reported in Eq. (38). When the variety-enhancing effect is sufficiently strong and the extent of firm heterogeneity is sufficiently small, the government can use its provision of public infrastructure as a policy instrument to attract more firms to enter the market. With this provision of public infrastructure, the welfare level will increase in response.[24]

A numerical analysis is carried out here to gain insights into how changes in plausible values of γ and κ govern the effect of fiscal policy on welfare. Figure 11 depicts the effect on welfare derived from our model, which is a function of γ and κ given that $\theta = 0.18$ and $\varepsilon = 0.23$. The range of the parameter γ is set to $\gamma\ \varepsilon\ [0, 0.6]$ and the range of the parameter κ is set to $\kappa\ \varepsilon\ (1, 5.6]$ as before. As we can see from Fig. 11, the $\gamma - \kappa$ space is divided into two areas. The gray area in the upper right corner represents the region featured by welfare gains (i.e., $\partial U/\partial G > 0$), while the white area to the left represents the region featured by welfare losses (i.e., $\partial U/\partial G < 0$). Accordingly, by restricting our analysis to these plausible values, a higher γ associated with a higher κ results in a positive effect on welfare. This numerical result confirms our theoretical analysis of Eq. (38): the expansionary fiscal policy can generate welfare gains, provided that the variety-enhancing effect is sufficiently strong and the extent of firm heterogeneity is sufficiently small. However, based on Fig. 11, it is quite obvious that under these plausible values a fiscal expansion is less likely to yield a positive effect on welfare.

The discussion in this section leads us to establish the following proposition:

Proposition 3 *Afiscal expansion may raise welfare when the love of variety is sufficiently strong and the extent of firm heterogeneity is sufficiently small, namely,* $\gamma[\theta(1-\theta)+\varepsilon] > \theta + \varepsilon/\kappa$.

[24] Among the existing studies on optimal fiscal policy, Reinhorn (1998) and Molana and Zhang (2001) find that fiscal policy may be welfare improving if government expenditure (e.g., libraries, national parks, national defense, and a variety of social security programs) enters into the household's utility function. Chang et al. (2018) point out that fiscal policy may raise the welfare level in the presence of the variety-enhancing effect. Compared with these existing studies, the result in Eq. (38) further indicates that fiscal policy leads to a welfare deterioration in the presence of firm heterogeneity in productivity.

7 Concluding remarks

This paper sets up an imperfectly competitive general equilibrium model featuring firm heterogeneity in productivity. The model delivers novel insights into the effects of a fiscal stimulus on both firm-level and aggregate-level variables. Several main findings emerge from our analysis. First, a rise in firm heterogeneity leads to decreases in aggregate output and aggregate consumption, but raises the aggregate price level when the variety-enhancing effect is sufficiently strong. Second, a fiscal expansion can result in a positive effect on aggregate consumption but a negative effect on the aggregate price level, provided that the variety-enhancing effect is relatively large or the extent of firm heterogeneity is relatively small. Finally, a fiscal expansion may raise social welfare, depending on the size of the variety-enhancing effect and the extent of firm heterogeneity.

While this paper sheds light on the macroeconomic effects of a fiscal stimulus in a general equilibrium model of imperfect competition with firm heterogeneity, it makes some assumptions to simplify the analysis. First, in line with Melitz (2003) and Melitz and Redding (2015), this paper ignores the accumulation of physical capital. It would be an interesting extension to set up an intertemporal optimizing model by bringing capital accumulation into the picture. With such an extended framework, not only are we able to tackle the related issues in this paper, but we can also explore the effects of growth on government spending.

Second, for analytical tractability and simplicity, this paper specifies that government spending on infrastructure tends to reduce a firm's fixed production costs. It would be interesting to specify that government spending on infrastructure would reduce both fixed and variable production costs rather than only fixed production costs. We can then examine whether the main results of our paper are robust with this alternative specification. However, this extension would make the analysis much more complicated than the one in this paper, and hence one should resort to numerical simulations. We leave this issue for future research.

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Appendix 1

In this appendix, we derive the comparative static results of a rise in firm heterogeneity.Totally differentiating Eqs. (21), (25) and (28) with respect to κ yields:

$$\frac{\partial \varphi^*}{\partial \kappa} = \frac{-\varphi^*}{\kappa^2}\left\{ \ln\left[\frac{(\sigma-1)f(G)}{(\kappa-\sigma+1)\delta f_e}\right] + \frac{\kappa}{\kappa-\sigma+1}\right\} < 0, \tag{39}$$

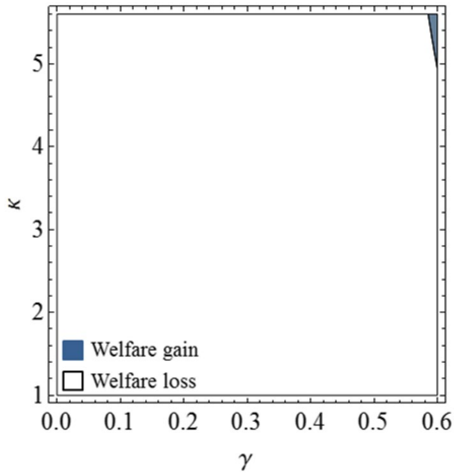

Fig. 11 The fiscal welfare gain and welfare loss regions

$$\frac{\partial\tilde{\varphi}}{\partial\kappa}=\frac{-\tilde{\varphi}}{\kappa}\left\{\frac{2}{\kappa-\sigma+1}+\frac{1}{\kappa}\ln\left[\frac{(\sigma-1)f(G)}{(\kappa-\sigma+1)\delta f_{\mathrm{e}}}\right]\right\}<0, \tag{40}$$

$$\frac{\partial\pi(\tilde{\varphi})}{\partial\kappa}=\frac{-(\sigma-1)f(G)}{(\kappa-\sigma+1)^2}<0. \tag{41}$$

Based on Eq. (40), from Eqs. (22) and (23) we can derive:

$$\frac{\partial p(\tilde{\varphi})}{\partial\kappa}=\frac{\sigma}{\kappa(\sigma-1)\tilde{\varphi}}\left\{\frac{2}{\kappa-\sigma+1}+\frac{1}{\kappa}\ln\left[\frac{(\sigma-1)f(G)}{(\kappa-\sigma+1)\delta f_{\mathrm{e}}}\right]\right\}>0, \tag{42}$$

$$\frac{\partial y(\tilde{\varphi})}{\partial\kappa}=\frac{-(\sigma-1)f(G)\,\tilde{\varphi}}{\kappa-\sigma+1}\left\{\frac{\sigma+1}{\kappa-\sigma+1}+\frac{1}{\kappa}\ln\left[\frac{(\sigma-1)f(G)}{(\kappa-\sigma+1)\delta f_{\mathrm{e}}}\right]\right\}<0. \tag{43}$$

With the help of Eqs. (42) and (43), totally differentiating Eqs. (35) and (36) with respect to κ yields:

$$\frac{\partial Y}{\partial\kappa}=\frac{-CY}{\kappa[C+(\gamma+1)G]}\left\{\frac{2-\gamma(\sigma-1)}{\kappa-\sigma+1}+\frac{1}{\kappa}\ln\left[\frac{(\sigma-1)f(G)}{(\kappa-\sigma+1)\delta f_{\mathrm{e}}}\right]\right\}\gtrless 0;\quad \text{if } \gamma\lesseqgtr\frac{2}{\sigma-1}+\frac{(\kappa-\sigma+1)}{(\sigma-1)\kappa}\ln\left[\frac{(\sigma-1)f(G)}{(\kappa-\sigma+1)\delta f_{\mathrm{e}}}\right], \tag{44}$$

$$\frac{\partial P}{\partial\kappa}=\frac{PY}{\kappa[C+(\gamma+1)G]}\left\{\frac{2-\gamma(\sigma-1)}{\kappa-\sigma+1}+\frac{1}{\kappa}\ln\left[\frac{(\sigma-1)f(G)}{(\kappa-\sigma+1)\delta f_{\mathrm{e}}}\right]\right\}\gtrless 0;\quad \text{if } \gamma\lesseqgtr\frac{2}{\sigma-1}+\frac{(\kappa-\sigma+1)}{(\sigma-1)\kappa}\ln\left[\frac{(\sigma-1)f(G)}{(\kappa-\sigma+1)\delta f_{\mathrm{e}}}\right]. \tag{45}$$

From Eqs. (13), (32), (33), (42), (44) and (45), we can obtain:

$$\frac{\partial L}{\partial \kappa} = \frac{LG}{\kappa[C + (\gamma + 1)G]} \left\{ \frac{2 - \gamma(\sigma - 1)}{\kappa - \sigma + 1} + \frac{1}{\kappa} \ln \left[\frac{(\sigma - 1)f(G)}{(\kappa - \sigma + 1)\delta f_e} \right] \right\} \gtreqless 0; \quad \text{if } \gamma \lesseqgtr \frac{2}{\sigma - 1} + \frac{(\kappa - \sigma + 1)}{(\sigma - 1)\kappa} \ln \left[\frac{(\sigma - 1)f(G)}{(\kappa - \sigma + 1)\delta f_e} \right], \tag{46}$$

$$\frac{\partial C}{\partial \kappa} = \frac{-CY}{\kappa[C + (\gamma + 1)G]} \left\{ \frac{2 - \gamma(\sigma - 1)}{\kappa - \sigma + 1} + \frac{1}{\kappa} \ln \left[\frac{(\sigma - 1)f(G)}{(\kappa - \sigma + 1)\delta f_e} \right] \right\} \gtreqless 0 \quad \text{if } \gamma \gtreqless \frac{2}{\sigma - 1} + \frac{(\kappa - \sigma + 1)}{(\sigma - 1)\kappa} \ln \left[\frac{(\sigma - 1)f(G)}{(\kappa - \sigma + 1)\delta f_e} \right], \tag{47}$$

$$\frac{\partial M}{\partial \kappa} = \frac{M}{\kappa[C + (\gamma + 1)G]} \left\{ \frac{(\sigma - 1)C + (\sigma + 1)G}{\kappa - \sigma + 1} + \frac{G}{\kappa} \ln \left[\frac{(\sigma - 1)f(G)}{(\kappa - \sigma + 1)\delta f_e} \right] \right\} > 0. \tag{48}$$

Appendix 2

This appendix provides a detailed derivation regarding the comparative static results of a fiscal expansion.

Totally differentiating Eqs. (21)–(23), (25) and (28) with respect to G yields:

$$\frac{\partial \varphi^*}{\partial G} = -\frac{\varepsilon \varphi^*}{\kappa G} < 0, \tag{49}$$

$$\frac{\partial \tilde{\varphi}}{\partial G} = -\frac{\varepsilon \tilde{\varphi}}{\kappa G} < 0, \tag{50}$$

$$\frac{\partial \pi(\tilde{\varphi})}{\partial G} = -\frac{\varepsilon(\sigma - 1)f(G)}{(\kappa - \sigma + 1)G} < 0, \tag{51}$$

$$\frac{\partial p(\tilde{\varphi})}{\partial G} = \frac{\varepsilon p(\tilde{\varphi})}{\kappa G} > 0, \tag{52}$$

$$\frac{\partial y(\tilde{\varphi})}{\partial G} = -\frac{\varepsilon(\kappa + 1)y(\tilde{\varphi})}{\kappa G} < 0, \tag{53}$$

where $\varepsilon = -f'(G)G/f(G) > 0$.

With the help of Eqs. (42) and (43), totally differentiating Eqs. (35) and (36) with respect to G yields:

$$\frac{\partial Y}{\partial G} = \frac{\left[\gamma + 1 + \frac{\varepsilon(1-\theta)(\gamma\kappa-1)}{\theta\kappa}\right]}{\theta(1+\gamma)+1-\theta} \gtrless 0; \text{ if } \left[1 + \frac{\varepsilon(1-\theta)}{\theta}\right]\gamma + 1 \gtrless \frac{\varepsilon(1-\theta)}{\kappa\theta}, \tag{54}$$

$$\frac{\partial P}{\partial G} = \frac{\left[\frac{(1-\gamma\kappa)\varepsilon}{\theta\kappa} - \gamma\right]P}{[\theta(1+\gamma)+1-\theta]\,Y} \gtrless 0; \text{ if } \left(1 + \frac{\varepsilon}{\theta}\right)\gamma \lessgtr \frac{\varepsilon}{\kappa\theta}, \tag{55}$$

where $0 < \theta\ (= G/Y) < 1$.

Based on Eqs. (52), (54) and (55), from Eqs. (13), (32) and (33) we can derive:

$$\frac{\partial L}{\partial G} = \frac{\left[1 + \frac{(1-\gamma\kappa)\varepsilon}{\kappa}\right]L}{[\theta(1+\gamma)+1-\theta]\,Y} \gtrless 0; \text{ if } 1 + \frac{\varepsilon}{\kappa} \gtrless \gamma\varepsilon, \tag{56}$$

$$\frac{\partial C}{\partial G} = \frac{(1-\theta)\left[\gamma + \frac{\varepsilon(\gamma\kappa-1)}{\theta\kappa}\right]}{[\theta(1+\gamma)+1-\theta]} \gtrless 0; \text{ if} \left(1 + \frac{\varepsilon}{\theta}\right)\gamma \gtrless \frac{\varepsilon}{\kappa\theta}, \tag{57}$$

$$\frac{\partial M}{\partial G} = \frac{\left(1 + \frac{\varepsilon}{\theta} + \frac{\varepsilon}{\kappa}\right)M}{[\theta(1+\gamma)+1-\theta]\,Y} > 0. \tag{58}$$

Then, based on Eqs. (56) and (57), from Eq. (1) we can derive:

$$\frac{\partial U}{\partial G} = \frac{\left\{\frac{\gamma[\theta(1-\theta)+\varepsilon]}{\theta(1-\theta)} - \frac{\theta\kappa+\varepsilon}{\theta(1-\theta)\kappa}\right\}}{[\theta(1+\gamma)+1-\theta]Y} \gtrless 0; \text{ if } \gamma[\theta(1-\theta)+\varepsilon] \gtrless \frac{\theta\kappa+\varepsilon}{\kappa}. \tag{59}$$

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