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Self-fulfilling Expectations, History, and Big Push: A Search Equilibrium Model of Unemployment

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We set up a search equilibrium model with general matching technologies to study the phenomenon of large-scale and persistent unemployment. Our emphasis is on dynamics. We find, in addition to self-fulfilling expectations, history or initial level of employment plays a nonnegligible role for selecting the equilibrium converging to the steady state with large unemployment. We also discuss some policy implications. We propose a method similar to the idea of big push in economic development for the economy trapped in the state of large unemployment to escape from it.

1 Introduction

The unemployment rate has been high and persistent in most industrialized countries, especially in Western Europe, for more than two decades. In the United Kingdom, for example, the unemployment rate has risen almost continuously since 1970 and now stands at over 10%. For the Common Market countries as a whole, the unemployment rate has been more than doubled between 1970 and 1980, and has again doubled since then.

These events are not easily accounted for by conventional wisdom of classical or Keynesian macroeconomic theories. The imperfect information of new classical models (e.g., Lucas, 1973; Sargent, 1973), the intertemporal substitution in labor of real business cycle theory (e.g., Kydland and Prescott, 1982; Hansen, 1986), and the sticky wages or prices of Keynesian models (e.g., Fischer, 1977; Phelps and Taylor, 1977) can generate fluctuations in unemployment, but they are not able to explain large-scale and persistent unemployment. The failure of the above lines of research is due to the fact that these models generate a unique steady state and an economy thus tends to return to this steady state which is independent of initial conditions and is insensitive to shocks.

The European experience has led to the development of alternative theories of unemployment. Two theories have been developed. One line is the research of multiple steady states pioneered by Diamond (1982) and another line is the research of hysteresis led by Blanchard and Summers (1986). In his pioneering work, Diamond (1982a) obtains multiple steady states of unemployment by constructing a search equilibrium model with trading externalities. The importance of obtaining multiple steady states lies in the possibility for an economy to end up at the steady state that corresponds to a low level of employment. In this way the model with multiple steady states of unemployment is able to explain the existence of large-scale unemployment. Although his multiple steady states are able to capture the phenomenon of large-scale unemployment, Diamond does not show explicitly under which condition an economy chooses the equilibrium path converging to the steady state with a large rate of unemployment. This is the issue of dynamics. This work was later done by Diamond and Fudenberg (1989). They use Diamond's (1982a) model to study how this economy selects the equilibrium path leading to a particular steady state. Recently, there have been many papers in the context of search equilibrium investigating the dynamics of equilibria (see Howitt and McAfee, 1988; Drazen, 1988; Mortensen, 1989, among others). All these papers conclude that self-fulfilling expectations are the only determinant of the eventual outcome.

In this paper, we argue that, in addition to self-fulfilling expectations, the location of current employment level or state variable (namely history) plays a nonnegligible role for picking the equilibrium leading to the steady state with large unemployment.[1] That is, the phenomenon of large-scale and persistent unemployment may not be due solely to self-fulfilling expectations but due also to historical states. Our reasoning is as follows. In order to generate multiple steady states, a source of externality is necessary. When the externality depends on a state variable (namely the level of employment), under certain circumstances it is possible for the effect upon individuals' optimal decisions of current state variables (history) dominating that of future state variables (self-fulfilling expectations). In this situation history alone determines an equilibrium leading to a particular steady state and expectations play no role. If, however, the effect of future state variables dominates individuals' optimal decision-making, self-fulfilling expectations select an equilibrium as is shown in conventional wisdom.

1 For a discussion about the relative importance of history versus expectations in determining an equilibrium path, see Krugman (1991).

This paper attempts to set up a model in the line of search equilibrium to achieve the above purpose. We introduce search and recruiting intensity in the model. The model follows Mortensen (1982), Pissarides (1984), and Howitt and McAfee (1987). However, it differs in various aspects. First, we focus on dynamics, whereas the first two authors studied the efficiency of an equilibrium and the latter authors studied multiple steady states. Second, our search and recruiting technologies are more general than theirs since, as will be seen, we use general functional forms. Third, since both sides of searching and recruiting in our model have a monopoly power for a job match, the wage is determined by a bargaining process. We analyze explicitly the determination of wage.

We must point out the similarity and the difference between our work and hysteresis theories of employment. There are two directions of research on hysteresis. One line is membership theories that are based upon the distinction between insiders and outsiders (see Lindbeck and Snower, 1986) and another is duration theories that are built upon the distinction between short-term and long-term unemployed (see Clark and Summers, 1982). In either approach the equilibrium is path-dependent in the sense that actual employment today affects equilibrium employment in the future. Our result that current level of employment or history selects an equilibrium in certain circumstances is thus compatible with the hysteresis theories. However, since our model permits self-fulfilling expectations to select an equilibrium under other situations, our result differs from hysteresis theories.

This paper also conducts policy analysis. A particular emphasis is the case in which an economy is trapped in the state with large unemployment. As under some circumstances history alone determines an equilibrium, it is difficult to change the status quo with a small change in policy. A policy to alter economic structure is called for. We propose a method similar to the idea of a big push in industrialization (Murphy et al., 1989) for an economy trapped in the state of large unemployment to escape from it.

The organization of this paper is as follows. We form a basic model in the next section, according to which we discuss the optimization problems of both a representative unemployed worker and a representative vacant firm in Sect. 3. Section 4 closes the model and analyzes the determination of wage rate. Section 5 examines equilibrium selection. Section 6 conducts long-run policy analysis. We conclude in Sect. 7.

2 The Basic Model

Consider an economy populated by workers and firms. There is a continuum of identical, long-lived, and risk-neutral workers indexed by a number in the closed interval [0, 1]. A worker owns one unit of labor endowment. There are also many (n) identical, risk-neutral firms, located uniformly in the interval [0, 1]. Firms have no endowments except identical fixed-coefficient technologies. With a technology, one unit of labor input produces an average y units of nonstorable output. A firm hires at most $1/n$ fraction of workers.[2] If a firm hires less than $1/n$ fraction of workers before a steady state is reached, we say it is a vacant firm. There are workers of two types, unemployed and employed, and jobs of two types, vacant and filled.

2.1 An Unemployed Worker

An unemployed worker seeks a vacant job. The arrival of a vacant job is assumed to be a Poisson process with a mean arrival rate a. If an unemployed worker finds no vacant job, he receives an unemployment subsidy s in terms of consumption goods. He may choose to raise the arrival rate of a job by increasing search effort β.[3] Moreover, it is easier for an unemployed worker to seek a job if vacant firms recruit more vigorously. One therefore finds $a = a[\beta, (1-e)\theta]$, in which θ is the level of recruiting effort per vacant job; $(1-e)\theta$ is then the average level of recruiting effort as, by construction, the fraction of vacant jobs equals that of unemployed workers.

We assume that a is nonnegative, twice continuously differentiable, strictly increasing, and strictly concave for all $\beta > 0$, and that $a_{(1-e)\theta} > 0$ and $a_{\beta(1-e)\theta} > 0$. These assumptions are standard except for the positive externality of $a_{\beta(1-e)\theta} > 0$. This assumption states that if vacant firms recruit more vigorously, a marginal arrival rate of a job offer for a given level of search effort increases. Finally, we assume that $a[\beta, (1-e)\theta] = 0$ implies either $\beta = 0$ or $\theta = 0$. This assumption states that if the arrival rate of a job is zero, either un-

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2 Implicit in this assumption is the capacity constraint. Here, we implicitly assume the special case in which the number of agents and jobs is the same. This assumption is made for simplicity. The same assumption has been made by, among others, Diamond and Maskin (1978), Mortensen (1982), and Diamond (1982b).

3 For example, one can spend more time finding a job, reading more advertisements in the newspaper, or making more interviews.

employed workers or vacant firms make no searching and recruiting effort respectively. Given these assumptions, the capitalized value of an unemployed worker satisfies the following equation

$$rH_u(t) = s + a[\beta(t), (1-e(t))\theta(t)][H_e(t) - H_u(t)] - \beta(t) + \dot{H}_u \ , \quad (1)$$

where $H_e(t)$ and $H_u(t)$ denote respectively the expected lifetime income for a person employed and unemployed at time t, and $\dot{H}_u$ denotes the time derivative of H_u. Equation (1) states that the instantaneous capitalized yield rH_u must equal what the worker expects to earn in the labor market: the sum of instantaneous unemployment subsidy and the capital gains. We assume that all individuals and firms face the same constant interest rate r. There are two sources of capital gains. One capital gain is due to the alternation of status from being unemployed to being employed, and the other, the variation of the valuation over time.

2.2 An Employed Worker

When a contact between an unemployed worker and a vacant job is made, the contact invariably leads to employment. The reason is that, by construction, jobs are identical, workers are homogeneous, and the amount of output is fixed. The contacted party then decides how to divide the gains from the job match. The wage rate w is determined by bargaining. This wage determination is analyzed in Sect. 4. Once the wage rate is set, the worker then works for the firm forever.

With the assumptions of identical jobs and homogeneous workers there is no reason for quitting or dismissal. However, in order to capture the insufficiency of or structural shift in demand, we assume an exogenous possibility for the termination of a job in each period. Each job is decayed according to a Poisson process with a mean rate $b > 0$. A greater rate indicates both less demand and more rapid structural change in the economy. The capital valuation for an employed worker satisfies the following equation

$$rH_e(t) = w(t) + b(H_u(t) - H_e(t)) + \dot{H}_e \ . \quad (2)$$

Equation (2) indicates that the free-market yield $rH_e(t)$ must equal what an employed worker expects to earn in the labor market: the sum of the instantaneous wage rate and the capital gains. The sources of capital gains are the same as those in Eq. (1).

2.3 A Vacant Job

A vacant firm recruits an unemployed worker to fill a vacant job. The arrival of an unemployed worker is assumed to be a Poisson process with a mean arrival rate α. The firm chooses the recruiting efforts[4] θ to increase the arrival rate and is subject to recruiting cost θ. The arrival rate is subject to an externality; namely, a vacant firm recruits more easily a worker if those unemployed $(1-e)$ exert greater search effort β. We therefore find $\alpha = \alpha[\theta, (1-e)\beta]$.

Assume that α is nonnegative, twice continuously differentiable, strictly increasing, and strictly concave for all $\theta > 0$, and that $\alpha_{(1-e)\beta} > 0$ and $\alpha_{\theta(1-e)\beta} > 0$. That $a_{\theta(1-e)\beta} > 0$ is an externality assumption. We assume further that $\alpha[\theta, (1-e)\beta] = 0$ implies $\theta = \beta = 0$. Given these assumptions, the capital valuation of a vacant job satisfies:

$$rV_v(t) = \alpha[\theta(t), (1-e(t))\beta(t)](V_f(t) - V_v(t)) - \theta(t) + \dot{V}_v \, , \tag{3}$$

where $V_f(t)$ and $V_v(t)$ are the expected lifetime income of a job that is filled and vacant respectively at t. This equation has the same interpretation as those of the preceding equations.

2.4 A Filled Job

A filled job receives $(y - w)$ units of instantaneous net output as it pays the matched worker the wage rate w. A filled job is subject to decay at the mean rate b. The capital valuation for a filled job satisfies

$$rV_f(t) = y - w(t) + b(V_v(t) - V_f(t)) + \dot{V}_f \, . \tag{4}$$

This equation has interpretation similar to those in the preceding equations.

2.5 The Alternation of the Employment Rate

The economy has a law of motion regarding the employment rate. The employment rate enlarges with increases in worker–job matches, and diminishes with increases in job termination. Specifically,

$$\dot{e} = [1 - e(t)]a(t) - e(t)b \, . \tag{5}$$

4 For example, a firm can advertise in the newspaper, magazine, or on television, or set up a strong recruiting department.

Equation (5) is a typical assumption about the motion of employment rate in a search equilibrium model.

3 Individual Optimization Problem

3.1 An Unemployed Worker's Problem

Denoting $H(t) = H_e(t) - H_u(t)$, $H(t)$ represents the expected lifetime income of an employed over an unemployed worker at time t. For convenience we call $H(t)$ the excess (lifetime) income. We therefore obtain the relation $\dot{H} = \dot{H}_e - \dot{H}_u$. Subtracting (1) from (2), we obtain

$$\dot{H} = [r + b + a(t)]H(t) - w(t) + s - \beta(t) \ . \tag{6}$$

We integrate (6) to determine $H(t)$ as follows[5]:

$$H(t) = \int_{\tau=t}^{\tau=\infty} \exp\Big\{-[r + b + a(\beta(\tau), (1 - e(\tau))\theta(\tau))(\tau - t)]\Big\} \times \\ \times \Big\{w(\tau) - s + \beta(\tau)\Big\} \mathrm{d}\tau \ . \tag{7}$$

If we let both $\beta(\tau)$ and $\theta(\tau)$ in (7) be optimal values of effort exerted in search and recruiting for all $\tau > t$, then $H(t)$ in (7) gives the optimal value of excess income of employment from t onwards. According to Eq. (7) both a larger wage and a greater search effort increase optimal excess income from a job, but a larger unemployment subsidy decreases this optimal excess income. Given the expected value of $H(t)$, one obtains $H_u(t)$ from (2) as

$$H_u(t) = \int_{\tau=t}^{\tau=\infty} \exp[-r(\tau - t)] \times \\ \times \Big\{s + a[\beta(\tau), (1 - e(\tau))\theta(\tau)]H(\tau) - \beta(\tau)\Big\} \mathrm{d}\tau \ . \tag{8}$$

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5 As the right-hand side of (6) is continuously differentiable (C^1) in the neighborhood of the initial point $(t_0, H(t_0))$, there exists a unique solution for $H(t)$. See Hirsch and Smale (1974, pp. 163–169), for the proof. For a solution of a nonhomogeneous, and nonautonomous differential equation, see also Hirsch and Smale (1974, pp. 99–102).

The lifetime income in Eq. (8) consists of the unemployment subsidy and the net expected excess income from a job contact. The expected excess income must be positive; otherwise an unemployed individual does not participate in seeking a job but stays unemployed. Given the nonnegative expected income $H(t)$, the employment rate e, and the vacant firms' recruiting efforts θ, an unemployed worker's problem is to choose an optimal level of search effort $\beta(\tau)$ for all $\tau \geq t$ to maximize his expected lifetime income $H_u(t)$. The individual's optimal effort $\beta(\tau)$ may then be found by pointwise maximization of (8) yielding[6]

$$a_\beta[\beta(\tau), (1-e(\tau))\theta(\tau)]H(\tau) = 1, \quad \forall\tau \geq t \ . \tag{9}$$

Equation (9) indicates that an unemployed worker makes a search effort in every period $\tau \geq t$ until the expected marginal revenue equals the marginal cost. This equation characterizes an unemployed worker's optimal search behavior. One summarizes the properties of optimal individual search behavior without proof in the following lemma.

Lemma 1: There exists a unique function $\beta(\tau) = \beta[(1-e(\tau))\theta(\tau), H(\tau)]$ that satisfies (9). $\beta[(1-e)\theta, H]$ is continuous and strictly increasing in both $(1-e)\theta > 0$ and $H > 0$. Moreover, $\beta[(1-e)\theta, 0] = 0$.

Lemma 1 involves the characteristics regarding an unemployed worker's optimal search behavior. Given a nonnegative expected excess income from a job, an unemployed worker searches strenuously if vacant firms recruit vigorously. Moreover, an unemployed worker also searches strenuously for a given level of firms' recruitment if the expected excess income increases. However, he seeks no jobs if the expected excess income from a job is zero, even when vacant firms recruit vigorously. The nonnegative expected excess income thus plays the role of the searching participation condition. When this condition is satisfied, an unemployed worker then decides on the optimal level of search. An individual's searching behavior is, thus, based not only on a participation condition but also on an incentive compatibility condition.

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6 The lifetime income H_e is common to all workers and is independent of β and θ. In deriving (9), we evaluate at the optimal β. For this reason, $\partial H/\partial\beta = \partial H_e/\partial\beta - \partial H_u/\partial\beta = 0$.

3.2 A Vacant Firm's Problem

For the problem of a firm with a vacant job, denote $V(t) = V_f(t) - V_v(t)$, in which $V(t)$ represents the expected excess income to employ an additional worker to fill a vacant job at time t. We obtain the relation $\dot{V} = \dot{V}_f - \dot{V}_v$. Subtracting (3) from (4), one obtains

$$\dot{V} = [r + b + \alpha(t)]V(t) - (y - w(t)) - \theta(t) \ . \tag{10}$$

One then solves by integrating (10) to find

$$V(t) = \int_{\tau=t}^{\tau=\infty} \exp\left\{-[r + b + \alpha(\beta(\tau), (1 - e(\tau))\theta(\tau)](\tau - t)\right\} \times \\ \times \left\{(y - w(t)) + \theta(\tau)\right\} d\tau \ . \tag{11}$$

If we let both $\theta(\tau)$ and $\beta(\tau)$ in (11) be the optimal recruiting and search efforts for all $\tau \geq t$, $V(t)$ in (11) is then the optimal excess income of employing an additional worker to fill a vacant job from t onwards. Given the value $V(t)$, we then obtain $V_v(t)$ from (4) as

$$V_v(t) = \int_{\tau=t}^{\tau=\infty} \exp[-r(\tau - t)] \times \\ \times \left\{[\alpha[\theta(\tau), (1 - e(\tau))\beta(\tau)]V(\tau) - \theta(\tau)\right\} d\tau \ . \tag{12}$$

$V_v(t)$ in (12) is the expected lifetime income for holding one more unit of vacant job from t onward. Given the nonnegative expected income $V(t)$, the employment rate e, and the unemployed workers' search effort $(1 - e)\beta$, a vacant firm's optimal recruiting level $\theta(t)$, for all $\tau \geq t$, is found by pointwise maximization of (12) yielding

$$\alpha_\theta[\theta(\tau), (1 - e(\tau))\beta(\tau)]V(\tau) = 1, \quad \forall\tau \geq t \ . \tag{13}$$

A vacant firm makes the recruiting effort until the expected marginal income equals marginal cost. We summarize the properties of the optimal level of recruiting effort in the following lemma:

Lemma 2: There exists a unique function $\theta(\tau) = \theta[(1 - e(\tau))\beta(\tau), V(\tau)]$ satisfying (13). $\theta[(1 - e)\beta, V]$ is continuous and strictly increases in both $(1 - e)\beta > 0$ and $V > 0$. Moreover, $\theta[(1 - e)\beta, 0] = 0$.

The properties summarized in Lemma 2 are intuitive. Given a nonnegative expected excess reward from a filled job, a vacant firm recruits vigorously if unemployed workers search strenuously. Given the seeking effort of unemployed workers, a vacant firm makes greater effort to recruit if the expected excess reward for a filled job increases. However, a vacant firm participates in no recruiting activity even when unemployed workers make much effort to seek jobs if the vacant firm cannot gain excess reward.

4 Equilibrium Wage

The system that we have described so far contains five equations: (5), (6), (9), (10), and (13). However, we have six unknowns: e, β, θ, V, H, and w. We close the model by adding a wage determination equation.

When an unemployed worker and a vacant firm meet, they negotiate the wage rate w. There are many theories for the determination of a wage rate.[7] As both the unemployed worker and vacant job of a match have monopolistic power over the match, the wage rate is determined by a bargaining process. We assume that the wage rate is determined according to static Nash bargaining (Nash, 1950) between the matched job and worker. The negotiation is accomplished instantaneously in equilibrium because of, by construction, continuous-time setting.

Theoretically, the bargaining process may be sequential. First, one bargaining party is selected randomly, with probability fifty percent to propose a partition to which the other party then reacts with acceptance or rejection. Acceptance of a proposal ends the bargaining. If a proposal is rejected, then the same bargaining procedure is repeated in the next time period. A bargaining process of this type was first studied by Rubinstein (1982). In equilibrium, the perfect equilibrium can be reached in one period.

Under the search framework in discrete time setting, Rubinstein and Wolinsky (1985) show the existence and uniqueness of a perfect equilibrium in the matching game played by the sequential bargaining parties, assuming the numbers of unemployed workers and vacant jobs are at steady levels. Without making the same assumption regarding the numbers of unemployed workers and vacant jobs as Rubinstein and Wolinsky, Binmore and Herrero (1988) show the existence and uniqueness of a perfect equilibrium for the sequential bargaining game given the positive time-preference rate. When the time-preference rate is positive, Binmore et al. (1986) show that the unique perfect bargaining

7 For example, the insider–outsider theory of Lindbeck and Snower (1986) and the efficiency-wage theory of Shapiro and Stiglitz (1984).

equilibrium approaches the static Nash bargaining solution if the time period of a bargaining is negligible. Therefore, the use of the static axiomatic Nash bargaining as the solution concept in the current paper is justified.

To apply Nash bargaining, the required information is a pair of utility functions that represent the parties' preferences over the match, and a pair of utility levels to which we refer variously as the status quo, the disagreement point, or the threat point. This information requirement is not difficult to satisfy. We have all the information needed.

As the threat point for an unemployed worker is $H_u(t)$, the surplus enjoyed by an employed worker is $H_e(t) - H_u(t)$. By the same token, because the threat point for a vacant job is V_v, the surplus enjoyed by a filled job is $V_f(t) - V_v(t)$. The generalized Nash rule indicates that a worker is expected to receive a fraction ρ of the total surplus and a filled job receives the remaining $(1 - \rho)$; ρ depends upon the relative number on both sides. The short side generally receives a larger share. As, by construction, the numbers on both sides are equal, ρ equals $1/2$.[8] Even if we use a general ρ, the qualitative results of the paper are not affected. Under $\rho = 1/2$, the static Nash bargaining solution is to solve the following problem:

$$\max_{\{w(t)\}} (V_f(t) - V_v(t))^{1/2}(H_e(t) - H_u(t))^{1/2} .$$

The necessary condition implies the following relation

$$V(t) \equiv V_f(t) - V_v(t) = H_e(t) - H_u(t) \equiv H(t) . \tag{14}$$

Equation (14) implies the relation $\dot{V} = \dot{H}$. In equilibrium, we obtain from (6) and (10) the following relation

$$\begin{aligned} &\big[r + b + a[\beta(t), (1 - e(t))\theta(t)]\big]V(t) - w(t) + s - \beta(t) = \\ &= \big[r + b + \alpha[\theta(t), (1 - e(t))\beta(t)]\big]V(t) - y + w(t) - \theta(t) . \end{aligned} \tag{15}$$

Then one finds $w(t)$ as

$$w(t) = \tfrac{1}{2}(s + y) + \tfrac{1}{2}\big[[a(t)V(t) - \beta(t)] - [\alpha(t)V(t) - \theta(t)]\big] . \tag{16}$$

8 Diamond (1982b), for example, also assumes $\rho = 1/2$ when applying the static Nash solution concept.

Equation (16) is the equilibrium negotiated wage rate. The wage rate is a weighted average of the sum of both unemployment subsidy plus output and the gap of capital gains. According to (16), the equilibrium wage rate is related to equilibrium levels of search β and recruitment θ. As both β and θ are in turn determined by the state and structural variables, e, V, and s, we therefore write the equilibrium wage rate as $w = w(e, V; s)$.

5 Equilibrium with Large Unemployment

We assume that individuals have perfect foresight about expected $H(t)$ and $V(t)$; perceived values of $H(t)$ and $V(t)$ are therefore equal to realized values of $H(t)$ and $V(t)$ respectively in equilibrium. The perfect-foresight equilibrium consists of six equations: (5), (6), (9), (10), (13), and (16). Equations (9) and (13) characterize individuals' optimal search and recruiting levels respectively. Their properties are summarized in the two functions in Lemmas 1 and 2. Inserting these two functions into the remaining equations, the equilibrium of the economic system is governed by only four equations.

As (16) is in turn characterized by $w = w(e, V; s)$, inserting this w into (5), (6), and (10), we reduce further the system to three equations. Moreover, from the wage bargaining in Sect. 4, one derives the relation of $\dot{H} = \dot{V}$. Equations (6) and (10) are therefore dependent. The equilibrium can be analyzed simply according to (5) and (10). We rewrite (5) and (10) in the steady state in the following manner

$$\begin{aligned} \dot{e} &= h(e, V) \\ &= (1-e)a\big[\beta[(1-e)\theta, V], \theta[(1-e)\beta, V]\big] - eb = 0 , \end{aligned} \tag{17}$$

$$\begin{aligned} \dot{V} &= k(e, V; s, r) \\ &= \big[r + b + \alpha[\theta((1-e)\beta, V], (1-e)\beta]\big]V - \\ &\quad - [y - w(e, V; s, r)] - \theta((1-e)\beta, V) = 0 , \end{aligned} \tag{18}$$

where $h_e = -a + (1-e)\left[a_\beta \dfrac{\mathrm{d}\beta}{\mathrm{d}e} + a_\theta \dfrac{\mathrm{d}\theta}{\mathrm{d}e}\right] - b < 0$,[9]

9 We show $\mathrm{d}\beta/\mathrm{d}e < 0$, $\mathrm{d}\beta/\mathrm{d}V > 0$, $\mathrm{d}\theta/\mathrm{d}e < 0$, and $\mathrm{d}\theta/\mathrm{d}V > 0$ in Appendix A.

$$h_V = (1-e)\left[a_\beta \frac{\mathrm{d}\beta}{\mathrm{d}V} + a_\theta \frac{\mathrm{d}\theta}{\mathrm{d}V}\right] > 0\ ,$$

$$k_e = \tfrac{1}{2}\left[-\beta\alpha_{(1-e)\beta} + \alpha_{(1-e)\beta}(1-e)\frac{\mathrm{d}\beta}{\mathrm{d}e} + a_\theta V \frac{\mathrm{d}\theta}{\mathrm{d}e}\right] V < 0\ ,$$ [10]

$$k_V = \left[r + b + \tfrac{1}{2}(\alpha + a)\right] + \\ + \tfrac{1}{2}\alpha_{(1-e)\beta}(1-e)\left[\frac{\mathrm{d}\beta}{\mathrm{d}V} + a_\theta \frac{\mathrm{d}\theta}{\mathrm{d}V}\right] > 0\ ,$$

$$k_s = \frac{1}{2} > 0\ , \quad \text{and}$$

$$k_r = V > 0\ .$$

We proceed to study steady states first. To do this, we require the slopes of the two curves. The slopes of the two curves $h(e, V) = 0$ and $k(e, V; s, r) = 0$ in the steady state are

$$\left.\frac{\mathrm{d}V}{\mathrm{d}e}\right|_{\dot{e}=0} = -\frac{h_e}{h_V} > 0\ , \quad \text{and} \tag{19}$$

$$\left.\frac{\mathrm{d}V}{\mathrm{d}e}\right|_{\dot{V}=0} = -\frac{k_e}{k_V} > 0\ . \tag{20}$$

According to (19) and (20) these two curves have positive slopes. With these two curves going in the same direction, there may not exist even a steady state with positive employment. In the following, we show the existence of an interior steady state.

Proposition 1: Under the assumptions about a and α in Sect. 2, there exists an interior (perfect-foresight) steady state. Moreover, there may exist an odd number of multiple steady states.

The first assertion is proved according to the intermediate-value theorem. We show that the curve $k(e, V) = 0$ starts from a value of V greater than that on the curve $h(e, V) = 0$ when $e = 0$, and that $k(e, V) = 0$ ends at a value of V less than that on $h(e, V) = 0$ when $e = 1$. As both curves $k(e, V) = 0$ and $h(e, V) = 0$ are continuous

10 In deriving k_e, k_V, k_s, and k_r, one utilizes the first order condition $\alpha_\theta V = 1$ in Eq. (13).

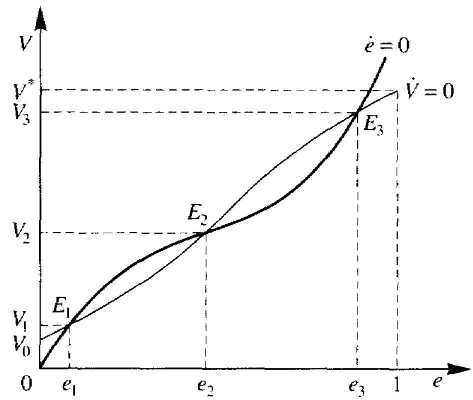

Fig. 1: Multiple steady-state equilibria

on $e \in [0, 1]$, there exists an interior pair (e, V) such that $h(e, V) = k(e, V) = 0$. The proof is in Appendix B.

In search equilibrium models with multiple steady states, an interior steady state is not guaranteed. Our model avoids this oddity. According to the above sketched proof, the crucial point lies in the fact that $\dot{V} = 0$ starts from a positive V, i.e., $V_0 > 0$ in Fig. 1. Our interpretation of this positive V_0 is as follows. When employment rate e is zero, it is easier for vacant firms to recruit. The vacant firms therefore exert some recruiting efforts $\theta(\beta, {}^*) > 0$. This situation in turn makes unemployed workers' search easier, and the unemployed workers thus make some search effort $\beta(\theta, {}^*) > 0$. Knowing that vacant firms and unemployed workers exert some recruiting and search efforts, all vacant firms and unemployed workers would expect a positive excess income of V_0 from a match before they start to recruit and search.

The possibility of multiple interior steady states is obvious. As both $\dot{e} = 0$ and $\dot{V} = 0$ are intrinsically nonlinear, we cannot guarantee one curve to be invariously steeper than the other. Therefore there may be multiple interior steady states (Drazen, 1987; Mortensen, 1989). In this situation the number of steady states is generically odd in our model. This condition is obvious as $\dot{V} = 0$ starts above $\dot{e} = 0$ and this economy has an interior steady state. In Fig. 1, we represent the case of three steady states. The case with an even number of steady states occurs with zero probability. When E_2 and E_3 in Fig. 1 coincide, for example, there are two steady states, therefore an even number. This case, however, is degenerate. Any small disturbance alters the number of steady states to one or three. Among the three steady states in Fig. 1, E_1 represents a case of large unemployment, E_2 represents a case of moderate unemployment, and E_3 small unemployment. Given the same underlying economic structure, this economy can find itself in diverse steady states. This economy possibly proceeds to a steady state with small or large unemployment.

Given the existence of a steady state with large unemployment, the question arises under which condition the economy selects the equilibrium converging to the steady state with large unemployment. This point is illustrated in our main proposition below using the case with three steady states.

Proposition 2: In the case with three steady states, under certain circumstances the economy chooses the equilibrium converging to the steady state with large unemployment if the initial employment rate is below some level; and under other conditions, self-fulfilling expectations determine the equilibrium.

To demonstrate Proposition 2, we need to examine the dynamic properties of each steady state and global dynamics. The dynamic properties of each steady state are proved in Appendix C. There we show that E_1 and E_3 are saddles, and E_2 may be a sink or a source depending upon the functional forms of α and a and the values of the parameters, r, s, b, and y.[11] As E_1 and E_3 are saddles, there exists a unique equilibrium trajectory respectively converging to E_1 and E_3. They are illustrated respectively by $W^s(E_1)$ and $W^s(E_3)$ in Fig. 2. Depending upon whether E_2 is a source or a sink, there is more than one possible configuration. We discuss these cases in Figs. 2 to 5. We employ these diagrams to shed light on the distinction between history versus self-fulfilling expectations in determining an equilibrium.

When E_2 is a source, the equilibrium trajectory may expand from E_2 in a monotonic or oscillating way depending upon economic structure. The economy moves eventually to either E_1 or E_3. These two cases are illustrated respectively in Figs. 2 and 3. These two diagrams exhibit thresholds in terms of employment level. In Fig. 2, when the current employment is below e_2, the economy chooses the unique equilibrium $W^s(E_1)$ converging to E_1, the steady state with large unemployment; otherwise, the economy chooses the equilibrium $W^s(E_3)$

11 For the definitions of saddle, sink, and source, see, for example, Hirsch and Smale (1974, pp. 89–97).

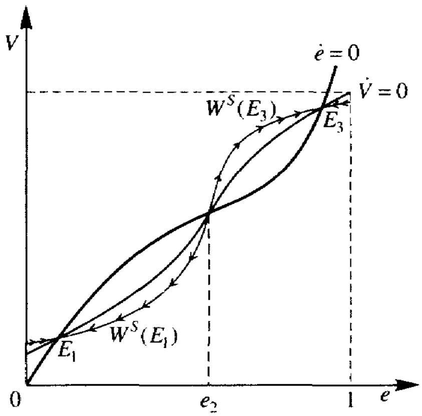

Fig. 2: A possible case where E_2 is a monotonic source

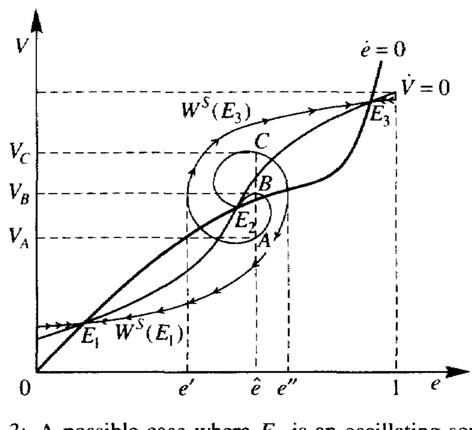

Fig. 3: A possible case where E_2 is an oscillating source

converging to E_3. So, under no situation do self-fulfilling expectations play a role in selecting an equilibrium in the case of Fig. 2.

In Fig. 3, the corresponding thresholds are e' and e''. In this case, when the initial employment level is below e' or above e'', history alone is capable of determining a unique equilibrium, and self-fulfilling expectations play no role. However, when the initial level of employment is between e' and e'', there is no unique equilibrium. In this condi-

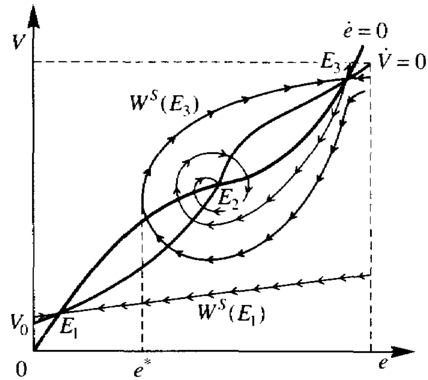

Fig. 4: A possible case where E_2 is a sink

tion the equilibrium may be $W^s(E_1)$ or $W^s(E_3)$, so both steady states E_1 and E_3 could be reached. Which equilibrium the economy chooses depends upon agents' expectations. For example, when the economy starts at $\hat{e}$ in Fig. 3, there are three expected V; V_A, V_B, and V_C, each corresponding to different expectations. When the expected V is at V_A or V_B, after finite periods of fluctuation in realized V the economy converges eventually to E_3. On the other hand, when the expected V is at V_C, the economy converges to E_1.

When E_2 is a sink, E_1, E_2, or E_3 would be reached eventually. We represent possible configurations in Figs. 4 and 5. Even in these two figures, history alone is able to determine an equilibrium under some conditions. In Fig. 4, the economy uniquely picks $W^s(E_1)$ converging to E_1 for current e smaller than e^*; and in Fig. 5, the economy uniquely chooses $W^s(E_3)$ converging to E_3 for current e greater than e^{**}. In other situations, the economy chooses an equilibrium that is not only possible to converge to E_1 and E_3, but also to E_2. As in the above analysis, which equilibrium the economy chooses depends upon economic agents' expected V.

Our above analysis thus indicates that not only self-fulfilling expectations but also history plays an important role in determining an equilibrium and therefore the steady state with small or large unemployment. As noted in the Introduction, previous works in search equilibrium models emphasize the role of self-fulfilling expectations in selecting an equilibrium. Our model provides another mechanism. Although this mechanism is not new in economics (Krugman, 1991), research in search equilibrium models has paid no attention to it. There is another

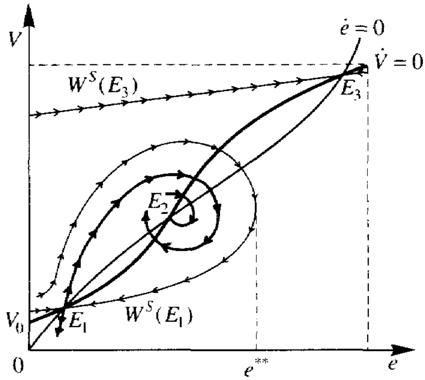

Fig. 5: A possible case where E_2 is a sink

line of research, hysteresis theories, that does emphasize current economic state or history to determine employment (Blanchard and Summers, 1986). But in this literature self-fulfilling expectations play no role. In the employment decision that is subject to an external effect and its payoff lasting many periods, it is curious to rule out self-fulfilling expectations as a mechanism to determine an equilibrium when an economic agent is endowed with perfect foresight.

Having demonstrated both mechanisms in deciding an equilibrium, we proceed to discuss policy implications when an economy is ended at the level of large unemployment. This is done in the next section to which we now turn.

6 Policy Implications

Because of the externality, all equilibria in Sect. 5 are inefficient. Moreover, the equilibrium with large unemployment is Pareto-dominated by the one with small unemployment. In the long run, one may seek to improve the Pareto-dominated equilibria, especially to escape from the equilibrium with large unemployment. To this end, one may need to change the underlying economic structure. In this section, we discuss policy implications in this direction.

According to Eq. (7) the expected excess lifetime income of employment is smaller when the unemployment subsidy s is larger. This smaller expected excess income becomes an individuals' disincentive for searching. That is, if the government reduces s, this action discour-

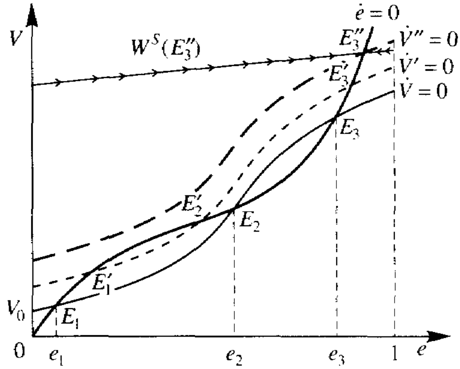

Fig. 6: A possible effect of reducing unemployment subsidies or increasing wage subsidies

ages the incentive to remain unemployed. The effects of reducing s on both $\dot{e} = h(e, V) = 0$ and $\dot{V} = k(e, V) = 0$ are seen in Eqs. (17) and (18). According to Eq. (17) s does not affect directly the steady-state law of motion of the employment rate directly. According to Eq. (18), the curve $\dot{V} = 0$ shifts upward for any given level of e if s is reduced because $k_s > 0$ and $k_V > 0$. This upward shift is intuitive because a reduced s increases the income gap between employed and unemployed and increases individuals' expected V.

However, if the upward shift in $\dot{V}$ is not large enough, one still obtains the same number of steady states in the neighborhood of old steady states. Figure 6 illustrates this case in which although the new steady states E_1' and E_3' are preferred to the old E_1 and E_3 respectively, the new E_2' is inferior to the old E_2. As one does not know where the economy is, this policy makes the economy worse if the economy is initially at E_2. Even when the steady state E_2 is a source, one confronts difficulty of another type as self-fulfilling expectations play an important role in choosing an equilibrium in the case of Fig. 3. We will come back to this point in the end of this section.

Nevertheless, if the government reduces s appropriately, the economic structure alters. The curve $\dot{V} = 0$ may shift upward sufficiently so that only one steady state exists. This unique point is represented by E_3'' in Fig. 6. As E_3'' is a saddle, there is a unique, invariant, perfect-foresight, equilibrium trajectory $W^s(E_3'')$ converging to it. The economy then moves along the unique equilibrium trajectory converging eventually to E_3'' from any initial employment level. We note that the idea to push an economy to the unique equilibrium leading to a better steady state is similar to that of a big push in the industrialization. They both seek a way to make an economy escape from the trapped steady state.

Even though this large reduction in unemployment subsidies is an *economically* preferred method as described above, the method may be *politically* infeasible because of conflicts with labor union's interest. Nevertheless this dilemma can be resolved. Instead of reducing unemployment subsidies, the government can subsidize the wage rate. This alternative policy has the same effect to increase search incentives as that of reducing unemployment subsidies. According to Eq. (7), both these policies increase the expected excess income of employment, and therefore stimulate individuals' incentives to seek jobs. Given the economic structure and the values of parameters s, b, r, and y, if we parameterize a and α, we calculate the minimal wage subsidy required to escape from large unemployment. *Theoretically*, parameterization of the model economy can be employed to obtain the correct magnitude for a big push. But, *in practice* it is not an easy task as will be discussed later. We note that the minimal wage subsidy required for a big push may be very large and thus render the policy infeasible.

Subsidy policy of a similar sort applies to vacant firms. According to Eq. (11) a subsidy to production increases the expected income gap between a filled and a vacant job, and thus increases the recruiting incentives. We interpret exerting large recruiting effort as making a large investment. We have two reasons for this interpretation. One is that, because workers work for the firm forever if recruited, recruiting activity resembles an investment. The other is that a larger investment implies a greater demand for labor and thus a greater recruiting effort. A subsidy to firms' production then stimulates investment. This objective might be achieved if the government uses a tax cut, tax credit, small rental of land, or low-interest long-term loan to encourage investment. Other things being equal, these policies raise firms' incentives to invest and thus increase demand for labor. Given the positive externality of the economy, this makes the search easier, therefore increases unemployed workers' incentives to seek employment.

The costs of search and recruitment discourage search and recruiting effort. Policies to diminish such costs enhance search and recruiting effort as they increase the expected excess income from a job match. The government may subsidize the search and recruiting cost. Alternatively, some effort to link the unemployed workers and vacant jobs may help to decrease these costs.

The decay rate b also affects searching and recruiting incentives. The excess income of employment is greater if b is smaller as the expected capital loss resulting from loss of the job is smaller. Unemployed workers therefore have a greater incentive to seek jobs. This parameter represents the sufficiency of or the structural shift in demand. The government can diminish the value of b by maintaining a sufficient level of demand and mitigating structural shift in demand. This aim may be accomplished by undertaking some public projects, for example, infrastructural investment. Policies along this line have been performed in some East Asian countries and have been successful (Wade, 1990). These actions are especially important when the economy becomes depressed (e.g., some negative shocks occur). As there are backward and forward linkages among industries, the decreased demand in one industry generally reduces analogously the demand in other industries because of the externality. The depression thus creates enhanced b. If no action is taken, individuals would expect a large capital loss and diminish the search and recruiting incentives. A bad steady state then results. Actions to maintain sufficient demand and mitigate structural shift in demand are thus necessary. Some traditional Keynesian fiscal policies can be useful in this respect.

We must point out, however, the restriction of a big push policy in practice. Although theoretically we can parameterize the model economy to acquire the correct magnitude required, if any, for a big push policy of the sort proposed in our work, it is in fact hard to achieve as in practice it is of difficulty to determine the correct figure. When this event takes place, there exist still multiple rather than a unique steady states if a big push policy of insufficient magnitude is conducted. In this case, a big push policy of insufficient magnitude is thereby indistinguishable from one of a small nudge and would run the jeopardy of piloting the economy toward a steady state with a larger unemployment rate. This result is led to when self-fulfilling expectations are of dominance in choosing an equilibrium and in the meanwhile individuals select the one leading to a steady state with large unemployment as one is not sure of where the equilibrium of the economy is located. In light of the unpredictable consequences of governmental policies, the incumbent may be more often than not reluctant to conduct active policies and prefers instead one of nonintervention, although nonintervention is by no means optimal in this circumstance.

We therefore have a dilemma. In an economy with multiple steady states in equilibrium in which self-fulfilling expectations are of importance in choosing an equilibrium as in our model, only a big push that reduces the number of steady states to unity one can predict the outcome of active policies. But, a big push policy of insufficient magnitude renders the result of the policy hazardous as the economy could be led to an even worse state depending upon both people's expectations and initial condition. The restriction of this kind in conducting active intervention manifests in part why unemployment rate has been high and persistent in Western Europe for so long a time.[12]

7 Concluding Remarks

We have developed a search equilibrium model with general matching technologies to study the phenomenon of large-scale and persistent unemployment. We shed light on dynamics in employment. We find that, in addition to self-fulfilling expectations, history or initial level of employment plays a nonnegligible role for selecting the equilibrium leading an economy to the steady state with large unemployment. We also discuss policy implications. We propose a method similar to the idea of a big push in economic development for the economy in the state of large unemployment to escape from it. In what follows, we discuss the restrictions in this work.

This model conducts only a partial equilibrium analysis. There is only one market in this model, namely the labor market. We know that the demand in another market may have ramifications on the labor market. For example, insufficient demand in commodity market may discourage firms' incentives undertaking recruiting or investment. This effect dampens workers' incentive to search and therefore diminishes further the effective demand in the commodity market.[13] However, the introduction of a commodity market would entangle this already complicated model. For our purpose, a partial (labor market) equilibrium suffices.

Another restriction in our work may be the assumption of an equal number of workers and jobs. Although this assumption has been made in the literature,[14] this assumption makes the role of vacant jobs passive. To make a job vacancy rate play the same role as an unemployment rate, we probably need to specify further law of motion for the job vacancy rate. Blanchard and Diamond (1989) included such a condition in the model in which only the laws of motion of both rates of employment and vacancy are contained. Adding this specification to the

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12 Restriction of a big push in this respect is reminiscent of that of a big push in the context of economic development which is evidenced by the fact that few developing economies have been pushed to a state of industrialization in past decades. For restriction of a big push in economic development and its implications, see Chen (1994).

13 Leijonhufvud (1968, 1973) makes an argument of this kind.

14 The same assumption has been made by many others; see references in footnote 2.

current model would make the economic structure three-dimensional and the equilibrium difficult to characterize. An alternative way is to assume competition among vacant jobs such that the lifetime income of a vacant job is zero, i.e., $V_v = 0$. Pissarides (1984, 1990) used this method. This specification, however, treats unemployment and a vacant job asymmetrically, namely that the job vacancy rate can increase instantaneously whereas the unemployment rate is staggered. In contrast we treated them both in a staggered and symmetric way. For the purpose of this paper, we consider this symmetric modeling strategy proper.

Appendix A
The Derivation of $d\beta/de < 0$, $d\beta/dV > 0$, $d\theta/de < 0$, and $d\theta/dV > 0$ in Footnote 9, Sect. 5

According to Sect. 3, one obtains $\beta = \beta[(1-e)\theta, V]$ and $\theta = \theta[(1-e)\beta, V]$. Totally differentiating these two equations, one finds

$$\begin{bmatrix} 1 & -(1-e)\beta_{(1-e)\theta} \\ -(1-e)\theta_{(1-e)\beta} & 1 \end{bmatrix} \cdot \begin{bmatrix} d\beta \\ d\theta \end{bmatrix} =$$
$$= \begin{bmatrix} \beta_V & -\beta_{(1-e)\theta}\theta \\ \theta_V & -\theta_{(1-e)\beta}\beta \end{bmatrix} \cdot \begin{bmatrix} dV \\ de \end{bmatrix} .$$

By using Cramer's rule, one derives the result. □

Appendix B
Proof of the First Assertion in Proposition 1

Before we prove, we need the lemma in the following.

Lemma 3: Let V_0 be the value of V such that $\dot{V}(0, V; s, r) = 0$. Then $\theta_0(\beta, V_0) > 0$ or $\beta_0(\theta, V_0) > 0$.

Proof: At $e = 0$, $\dot{e} = a[\beta(\theta, V), \theta(\beta, V)] = 0$. This condition implies that $\beta(\theta, V) = 0$ and $\theta(\beta, V) = 0$. One solves to obtain $V = 0$. Furthermore $\dot{V} = \{r + b + \alpha_0[\theta_0(\beta_0, V_0), \beta_0(\theta_0, V_0)]\}V_0 - (y - w_0) - g(\theta_0) = 0$ at $e = 0$, in which the subscript 0 denotes the variables evaluated at $e = 0$. It suffices to show that either $\theta_0(\beta_0, V_0) > \theta(\beta, 0) = 0$ or $\beta_0(\theta_0, V_0) > \beta(\theta, 0) = 0$ as $d\theta/dV > 0$ and $d\beta/dV > 0$

according to Appendix A. From $\dot{V} = 0$, one obtains

$$(r + b)V_0 - y = -\alpha_0(\theta_0, \beta_0)V_0 - w_0 + g(\theta_0) . \tag{3.1}$$

One also derives $\dot{V} = \{r + b + \alpha_1[\theta_1(0, V_0), \beta_1(\theta_1, V_0)]\}V_0 - (y - w_1) - g(\theta_1) < 0$ when evaluating at $(e = 1, V = V_0)$, in which the subscript 1 denotes the variables evaluated at $e = 1$. From this equation, one obtains

$$(r + b)V_0 - y < -\alpha_1(\theta_1, \beta_1)V_0 - w_1 + g(\theta_1) . \tag{3.2}$$

Inserting (3.1) into (3.2), one obtains $(\alpha_0 - \alpha_1)V_0 + (w_0 - w_1) - [g(\theta_0) - g(\theta_1)] > 0$. According to Eq. (16) in Sect. 6 for the expression of the equilibrium wage, we insert therein the wage expression to obtain

$$\begin{aligned} &\tfrac{1}{2}\{(a_0 - a_1)V_0 + (\alpha_0 - \alpha_1)V_0 - \\ &\quad - [f(\beta_0) - f(\beta_1)] - [g(\theta_0) - g(\theta_1)]\} > 0 . \end{aligned} \tag{3.3}$$

All θ's and β's are nonnegative. Three cases result:

case 1 either $\theta_0 > \theta_1 \geq 0$ or $\beta_0 > \beta_1 \geq 0$;

case 2 $\theta_0 = \theta_1 \geq 0$ and $\beta_0 = \beta_1 \geq 0$;

case 3 $\theta_1 > \theta_0 \geq 0$ and $\beta_1 > \beta_0 \geq 0$.

If case 2 is true, the left side of (3.3) is 0; one obtains $0 > 0$, which is a fallacy. The left side of (3.3) is negative if case 3 is true; one acquires a negative number, another fallacy. Only case 1 is true. □

We now start to prove the first assertion in Proposition 1. At $e = 0$, $\dot{e}(0, V) = a[\beta(\theta, V), \theta] = 0$. This condition implies either $\beta(\theta, V) = 0$ or $\theta(\beta, V) = 0$ from the assumptions made in Sect. 2, and therefore implies a value $V = 0$ from Lemmas 1 and 2. Note that $\dot{V}(0, V; s, r) = [r + b + \alpha(\theta, \beta)]V_0 - (y - w) - g(\theta) = 0$ implies $\theta(\beta, V_0) > 0$ and $\beta(\theta, V_0) > 0$ from Lemma 3. We therefore obtain a $V_0 > 0$ because $\mathrm{d}\theta/\mathrm{d}V > 0$ and $\mathrm{d}\beta/\mathrm{d}V > 0$ as shown in Appendix A and $\beta = \theta = 0$ when $V = 0$ in Lemmas 1 and 2. This result verifies that $\dot{V}(e, V; s, r) = 0$ starts from a positive V_0, which exceeds the value at which $\dot{e}(e, V) = 0$ starts.

At $e = 1$, $\dot{e}(1, V) = -b < 0$. Therefore V diverges. When $e = 1$, $\dot{V}(1, V; s, r) = [r + b + \alpha(\theta, 0)]V^* - (y - w) - g(\theta) = 0$ implies

$V = V^* < \infty$. This result shows that $\dot{V} = 0$ ends at a value of V less than that at which $h(e, V)$ ends.

With the results above and the continuity of $\dot{V}(e, V; s, r) = 0$ and $\dot{e}(e, V) = 0$, $\forall e \in [0, 1]$, the curve $\dot{V}(e, V; s, r) = 0$ must pass $\dot{e}(e, V) = 0$ at least once according to the intermediate-value theorem. This fact guarantees the existence of an interior steady state. □

Appendix C
Proof of the Local Dynamic Property for Each Steady State

Let $E_i = (e_i, V_i)$, $i = 1, 2, 3$, be the three steady states in Fig. 1. By linearizing both $\dot{e}(e, V) = 0$ and $\dot{V}(e, V; s, r) = 0$ at each steady state, one derives:

$$\begin{bmatrix} \dot{e} \\ \dot{V} \end{bmatrix} = \begin{bmatrix} h_e & h_V \\ k_e & k_V \end{bmatrix} \cdot \begin{bmatrix} e - e_i \\ V - V_i \end{bmatrix} .$$

Accordingly, one finds

$$\begin{aligned} \text{Trace} &= \dot{e}_e + \dot{V}_V \ , \\ \text{Det} &= \dot{e}_e \dot{V}_V - \dot{V}_e \dot{e}_V = -\dot{e}_V \dot{V}_V [(-\dot{e}_e/\dot{e}_V) - (-\dot{V}_e/\dot{V}_V)] \\ &= -\dot{e}_V \dot{V}_V \{(\text{slope of } \dot{e} = 0) - (\text{slope of } \dot{V} = 0)\} \ . \end{aligned}$$

When the steady state is at E_1 or E_3, the determinant is negative as the slope of $\dot{e} = 0$ is steeper than that of $\dot{V} = 0$. Both E_1 and E_3 are therefore saddles. Since the determinant at E_2 is positive and the trace is ambiguous, E_2 can be a source or a sink. □

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