How Productive is Optimism? –A Simple Keynes-type "Big Push" Model[1]

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Abstract

The paper examines the impacts of ambiguity and ambiguity attitudes on macroeconomic "Big Push" model. By formally modelling ambiguity, optimism and pessimism in economic industrialization, we show the results with Keynesian flavour: Sufficient optimism can create the "Big Push" to help the economy achieve Pareto-optimal equilibrium and sufficient pessimism cause economies to become "stuck" in an inefficient state.

Keywords: Ambiguity, Pessimism, Optimism, “Big push”

JEL Classification: D81, E32, H32

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1 Introduction

1.1 Ambiguity and Expectation

Keynes has presented his extensive thoughts about uncertainty and expectation formation in *The General Theory* (Keynes (1937)). In his views, as the core of Keynes' conception of economic society, uncertainty is not objectively measurable and quantifiable. Facing uncertainty, people look to the current facts, the average state of opinion and the state of confidence to form their expectation. Moreover, the dependence of people for each other on the formation of their expectation opens up the possibility of sudden mass change of these expectation. These visions of Keynes uncertainty and expectation has undermined the foundation of the rational expectations and the policy arguments that flow from it. Keynes argued that expectations and uncertainty are important motive forces on macroeconomic activities. In his view, investors' expectations play a vital role in determining the level of their investment which can aggregately lead to an increase(decrease) in macroeconomic activities via the multiplier process. Therefore uncertainty and the associated instability of expectations can be seen as underpinning the instability of investment, which in turn is the main key to more general macroeconomic instability. Sudden shifts in the psychological forces behind uncertainty ("animal spirit" in Keynes' words) can produce booms or slumps in the economy.

These views on uncertainty and expectation have received a substantial development since Keynes. The study of these ideas has found wide application for asset pricing, macroeconomic fluctuations and growth theory. However, it may appear surprising that the ideas have not been modeled more rigorously. One way around the difficulties is how to model uncertainty. In Keynes' opinion, uncertainty is impossible to express in exact probability and seemingly incompatible with the traditional notion of equilibrium.[2] Therefore we can not just simply predict economic behavior, particularly investment, as the outcome of a weighted average of quantitative benefits multiplied by quantitative probabilities (Keynes (1937)). The purpose of this paper is to shed light on solving this issue of more rigorously formulated Keynesian models. In doing so, we attempt to understand the importance of ambiguity and expectation by looking at a simple stylised model of a less developed economy in which optimistic expectation can greatly help generate a big push. The main methodology used here is to apply Choquet Expected Utility (CEU) to model economic firms' investment decisions in economy industrialisation process.

With a strong axiomatic foundation and reasonable experimental evidence, CEU is most commonly used one of alternative decision theories to Expected Utility. Since the 1930s, a significant number of studies on decision theories under uncertainty has been inspired by experimental evidence[3], which suggest that decision behaviour does not conform to classical Expected Utility.[4] In these theoretical works, uncertainty follows the formal definition from Knight (1921) which is regarded as one

[2]The literature on Keynesian theories are gargantuan. As a pioneering post Keynesian, G.L.S. Shackle insisted on the importance of real uncertainty and focused on moving away from probability-based resolutions for uncertain economies. See Ford (1994)

[3]See Ellsberg (1961) for a representative example.

[4]these alternative theories include, for instance, maximin expected utility (Gilboa and Schmeidler (1989)); incomplete preference (Bewley (1986)); generalised expected utility(Machina (1982)); regret theory (Bell (1985), Loomes and Sugden (1986)) and anticipated utility theory (Quiggin (1982)).

type of interpretation of Keynesian uncertainty: uncertainty is a situation where probabilities are imperfectly known or unknown. In CEU, individual's beliefs under uncertainty are represented as non-additive probabilities (or capacities) which are unique and subjective, whereas they do not satisfy all the properties of mathematical probabilities. With such beliefs, an individual makes his/her decision by maximising the utility named as CEU while behaving as either ambiguity-aversion (pessimism) or ambiguity-lover (optimism). The approach is superior in the sense that we incorporate Keynesian features of uncertainty and expectation while still maintaining optimising behaviour.

We label our model as Keynes-type in the sense that we capture two aspects of Keynes' arguments. First the model has two crucial ingredients of Keynes-type: specialisation and imperfect competition. Second, our results reflect Keynes' ideas on the impacts of uncertainty and expectation on economic activities.

1.2 "Big Push"

Firstly introduced by Rosenstein-Rodan (1943), the " Big Push" can be interpreted as the switch of economy from one equilibrium to a better equilibrium path without any exogenous improvement. This switch happens through simultaneous industrialisation (coordinated investment) across a sufficient enough number of economic sectors. As argued in Murphy, Shleifer, and Vishny (1989), there are a few important factors in the "Big Push". Firstly, it is assumed that world trade is not free and costless therefore market size is deemed to be important for economic growth; secondly, the precondition for "Big Push" is the coexistence of multiple, Pareto-ranked equilibria which implies that the economy is capable of sustaining two alternative levels of industrialisation; thirdly, with fixed preferences, endowments and available technologies in the economy, strategic complementarity and possible coordinated action across economic sectors are present.

Under these common features of "Big Push" literature, the basic story is that strategic complementarities among sectors generated through expenditure-demand rather than profit-demand link give rise to the source of multiplicity of equilibria. With the presence of strategic complementarity, the coordination among sectors pushes an economy to a better equilibrium. It is noteworthy that strong positive spillover across the sectors through profits is not necessary for the "Big Push". The previous studies show, if the positive spillover is generated through profits, then equilibrium is unique; however if an industrialising firm raises the size of other firms' markets even when it itself loses money, multiple equilibria arise naturally. In other words, even each industrialised firm can not break even individually with its investment, the strategic complementarity across firms imply that simultaneously coordinated investment of sufficiently many firms will make industrialisation self-sustained.

Therefore it is easy to see that macroeconomic externality and strategic complementarity play very important roles in "Big Push", which are also focus of most previous studies on this topic. The externalities have been modelled through different channels: labour movement, a rise in labour income (wage), also through intertemporal aspect (dynamic part). For instance, Murphy, Shleifer, and Vishny (1989) modelled that a firm losing money can benefit firms in other sectors because it raises labour income and hence demand for their products. They also examined the intertemporal aspect of industrialisation in a dynamic framework and showed that industrialisation today with negative net present value can generate a positive cash flow in the future which raises the demand for the output in other sectors. This framework of modelling externality has also been applied to analyse investment problems. (see Shleifer and Vishny (1988) and Fatas and Metrick (1997)) Such literatures reached similar results in the term of investment activities. By ignoring positive spillover of their investments through the channels of labour productivity or market size, firms underinvest. Pareto-efficient levels of investment happen once this positive externality is internalised.

Although literatures on this topic have been well established, the emphasis of this paper, inspired by Keynesian ideas, is instead on the impacts of ambiguity and confidence on the “Big Push”. Like all other literature, we chiefly associate the "Big Push" with multiple equilibria of the economy and interpret it as a switch from the non-industrialisation equilibrium to industrialisation equilibrium. But we are interested in the following question: Since a model of "Big Push" is insufficient to predict an outcome, what else do we need to fundamentally complete the description of such a strategic situation? By parallel reasoning, except technologies, preferences, endowments as descriptive elements in an economic environment, do we need to consider the expectation as suggested by Keynes? Can we reach some new results by abandoning the use of probabilistic ambiguity in strategic interaction? To answer these questions, we construct the model in line with the investment model in Fatas and Metrick (1997), whilst acknowledging that the expectations and ambiguity play a role in the estimates of the profit-stream of any newly-to-be-purchased plant or machinery. In this model, uncertainty can regard to different things: input costs, demand, or shocks such as technological developments. In this paper we assume that the ambiguity is about market demands. Strategic complementarity is created through altering the composition of demand. In other words, demand externality happens when the investment cost of an industrialised firm can add to the demand for the products of other firms. Thus, market demand crucially depends on the potential productivity of other firms. Facing such ambiguity, we showed that different expectations can be strong enough to generate different economic equilibrium states. In particularly, in an ambiguous situation, sufficient pessimism will result in the lowest level of economic activities and depression, and in comparison, sufficient numbers of optimistic agents will play higher strategies (industrialisation) simultaneously, thus "big push" arises to self-fulfilled “economics of euphoria”. We suggest these results are a good illustration of Keynesian views, that expectations under ambiguity by themselves can cause the economy’s output to expand or contract.

The paper is organised as follows. Section 2 introduces the basic method to model ambiguity and beliefs under ambiguity. Section 3 presents the set-up and shows the presence of two levels of equilibrium in economic activities. Section 4 models the effects of ambiguity and its attitudes on firms’ decision. Section 5 concludes.

2 CEU Preference with Neo-additive Capacity

Traditionally it assumes that decision makers have an expected utility preference. We wish to model the effects of ambiguity and hence, assume instead, that the decision makers have Choquet expected utility. In this section, we present the concept of CEU, an expected value of a function with an individual's belief represented by neo-additive capacity when there is exogenous uncertainty. Neo-additive capacity, denoted by v, models both optimistic and pessimistic attitudes towards ambiguity. The representation in this paper has an axiomatic foundation and proof in Chateauneuf, Eichberger and Grant (2007).

Considering an economic agent whose profit may depend in part on the behaviour of others. Let S_{-i} denote the set of action profiles for all agents except i. The notation s_{-i}, indicates a subset of S_{-i}.

A neo-additive capacity is defined as below.

Definition 2.1 *For a pair of real numbers such that $\lambda \succeq 0, \gamma \succeq 0,\ \lambda + \gamma \preceq 1$ and a given probability $\pi(A)$, a neo-additive capacity is defined as:*

$$v(A) = \begin{cases} 1 & \text{for } A = S \\ \lambda + (1 - \lambda - \gamma)\,\pi(A) & \text{for } \Phi \subsetneqq A \subsetneqq S \\ 0 & \text{for } A = \Phi \end{cases}$$

It is easy to see neo-additive capacity is a convex combination of an additive probability and probabilities on two extreme outcomes, one is complete ignorance with objective probability of 1 and one is complete ambiguity with objective probability of 0.

The Choquet integral with respect to neo-additive capacities forms a general preference representation where optimistic and pessimistic responses to ambiguity are modelled as over-weighting either the worst outcome or the best outcome.

Definition 2.2 *The Choquet expected value of a utility function* $u : S \to R$ *with respect to a neo-additive capacity* v *is defined as:* $CEU(v) = \int u dv = \gamma \cdot \inf_{s \in S}(u) + \lambda \cdot \sup_{s \in S}(u) + (1 - \lambda - \gamma) E_\pi(u)$, *where* $\inf_{s \in S}(u) = \min_{s_{-i} \in S_{-i}} u_i(s_i, s_{-i})$, $\sup_{s \in S}(u) = \max_{s_{-i} \in S_{-i}} u_i(s_i, s_{-i})$, *and* $E_\pi(u)$ *denotes the expected value of utility with respect to the probability distribution* π *on* S_{-i}.

It says that payoff of any strategy is valued by a weighted average of the expected payoff and the maximum and minimum payoffs for given S_{-i}. With beliefs represented as neo-additive capacities, a decision-maker still has probability distribution π on the events, however, (s)he assigns the weight $(1 - \lambda - \gamma)$ to π to represent his(her) confidence on the probability judgement. Interpreting $\gamma + \lambda$ as the degree of ambiguity, we have a decision-maker's beliefs as additive subjective probability π when there is no ambiguity and $\gamma + \lambda = 0$. With $\gamma + \lambda > 0$, a decision-maker can react to the ambiguity in part optimistically and in part pessimistically. In this definition, we say that the parameters λ and γ respectively represent the degrees of optimism and pessimism. A decision-maker is a pessimist if, in the presence of ambiguity, (s)he emphasises lower payoffs, and is an optimist if, instead, (s)he emphasizes higher payoffs.[5] The higher the ambiguity, the higher the emphasis on the extreme values, which mean the higher γ or λ is. The simple cases will be $\gamma = 0$ or $\lambda = 0$.

Definition 2.3 *A player is a pessimist if he uses the choice criterion:* $CEU(v) = \int u dv = \gamma \cdot \inf_{s \in S}(u) + (1 - \gamma) E_\pi(u)$ *and an optimist if he uses* $CEU(v) = \int u dv = \lambda \cdot \sup_{s \in S}(u) + (1 - \lambda) E_\pi(u)$ *as the choice criterion.*

[5] Wakker (2001) provides precise definitions of optimism and pessimism in CEU models.

The analysis can be complicated if we consider the case in which both γ and λ are positive and big number. The sum $\gamma + \lambda$ is consequently big and represents high level of ambiguity. There is a considerable amount of experimental evidence which suggests a decision-maker either behaves pessimistically or optimistically in such ambiguous situations (See Camerer and Weber (1992), or Cohen, Jaffray, and Said (1985)). However there is no experiment to show that an individual has both behaviours at the same time. Therefore we argue that it is sufficient to analyse optimism (pessimism) in a pure form for which CEU with respect to neo-additive capacity is easily applied. For the case in which both γ and λ are moderately big, we focus on the impacts of ambiguity represented by $\gamma + \lambda$ rather than separately on γ or λ.

Next, we use a simple binary game to illustrate how to apply these techniques.

2.1 Example

Consider a simultaneous move game with two players (firms), A and B. Each player is deciding to play either low strategy, labelled as "L", or high strategy, denoted as "H". "H" gives a highest payoff if the other sector choose "H" too. Payoffs are given by the following matrix, where $M > m > 0$, $l > 0$.

	H	L
H	M, M	$-l$,0
L	$0, -l$	m, m

This is a simple coordination game with strategic complementarity, and we have at least two Nash equilibria (without considering ambiguity), (H, H) and (L, L). In the first, both players make higher efforts but get higher payoffs. While in the second, both stay with lower technology and lower payoff. Industrialisation is a feasible and socially desired but not the only equilibrium choice for players. Player 1 might not play H for the fear that player 2 stay with L, and this in turn ensures that player 2 doesn't play higher strategy. It is easy to see that standard equilibrium refinements have no power to reduce the set of equilibria.

Now we consider ambiguity in the game which concerns the possible play of others. If we know players' ambiguity attitude, we shall know which equilibrium outcome will be played in the game.

Consider optimistic beliefs prevail in the game, naturally we shall have < H, H > as the equilibrium. Suppose, if possible, a <L, L> equilibrium exists, the payoff for player 1 is,

$$P_1(H, v_1) = M \cdot \lambda - l \cdot (1 - \lambda) = (M + l) \cdot \lambda - l$$

$$P_1(L, v_1) = m \cdot \lambda + (1 - \lambda) \cdot m = m.$$

It is easily to see when $\lambda > \frac{m+l}{M+l}$, L is not an optimal choice for player 1. We would interpret $\lambda > \frac{m+l}{M+l}$ as meaning that player 1 is optimistic about player 2 choosing H as the equilibrium strategy. In other words, when players' optimism is greater than certain level, they will choose H as the equilibrium strategy. Conversely, when $\lambda < \frac{m+l}{M+l}$, L is chosen in the equilibrium. We see that the threshold level of optimism for equilibria to switch is $\frac{m+l}{M+l}$. Clearly, the value of $\frac{m+l}{M+l}$ depends on the values of M, m and l. Inequality $\lambda > \frac{m+l}{M+l}$ also says that H is more likely to be played, the higher is the payoff M from playing H, or the lower is the payoff m from playing L. We know that these factors don't affect Nash solutions. In our opinion, our results are more plausible.[6]

Conversely, suppose players are sufficiently pessimistic and $\lambda = 0$, <L, L> is naturally the only equilibrium. Similarly assuming that H could be played in the equilibrium, then,

$$P_1(H, v_1) = -l \cdot \gamma + M \cdot (1 - \gamma) = M - (M + l) \cdot \gamma$$

$$P_1(L, v_1) = 0.$$

If $\gamma > \frac{M}{M+l}$, <H, H> will not be the equilibrium, player 1 will choose L in the equilibrium. Similarly, inequality $\gamma > \frac{M}{M+l}$ says that the lower is the payoff from playing H, the more likely the player will choose L as the equilibrium strategy.

Thus we conclude that, if both players are sufficiently optimistic (considering $\gamma \to 0$), <H, H> is the only equilibrium. Conversely, if both players are sufficiently pessimistic (considering $\lambda \to 0$), <L, L> is the equilibrium selected. Next we illustrate these ideas in a formal "Big Push" model.

3 A Benchmark "Big Push" Model

As a benchmark for the rest of the paper, this section introduces a highly stylised model which is in line with Fatas and Metrick (1997), and comes closest in its spirit to Shleifer and Vishny (1988)[7]. Later sections of the paper will put the roles of

[6] The result is consistent with the one from Eichberger and Kelsey (2000), where they use simple capacity to model player's beliefs.

[7] Although Fatas and Metrick (1997) is about irreversible investment and Shleifer and Vishny (1988) is about economic industrialisation, they are in the same framework. Thus we think the approach and results showed in our paper can be applied to both topics of investment and economic growth.

ambiguity and expectation into the model.

In the model the economy is restricted to one-period. There are multiple continuum sectors in the economy which are indexed by i on the unit interval $[0, 1]$. There are two types of firms in each sector, one is a competitive fringe of firms with a constant returns to scale (CRS) technology which convert one unit of input into one unit of output, i.e., $q_i = n_i$. The other is referred to as a monopolist who is able to access to two types of technologies, low and high productivity technologies. The low technology is free CRS technology but superior to the competitive fringe with marginal cost of 1. The adoption of low technology represents the non-industrialisation state of an economy. The high technology, representing the industrialisation, will incur a fixed cost which is the same to all industrialising sectors for the sake of simplicity. The only cost of production is labour, denoted by N, which is inelastically supplied by a single representative consumer. The representative consumer owns all claims to profits in the economy, and maximizes

$$U = \exp\left[\int_0^1 \ln(x_i)\, di\right]. \tag{1}$$

This is a typical Cobb-Douglas utility function for a continuum of goods, where each good is assumed to have the same share. This formulation implies identical consumption shares across sectors and unit elastic demand for all goods. Define y_i as the expenditure in each sector i, then the budget constraint is equal to

$$Y = \int_0^1 p_i x_i di = \int_0^1 y_i di = \Pi + W, \tag{2}$$

where Y is aggregate income (expenditure), Π represents aggregate profits by all firms and W represents total wages. Since consumption allocates identical share along sectors, expenditure in each sector, y_i will equal to Y by normalising on the unit interval.

Now considering two technologies available for the monopolist in each sector, we use superscript "l" and "h" separately represent low technology and high technology. The production function for low technology is : $q_i = \alpha_l n_i$ where $\alpha_l > 1$. Because the demand is unit-elastic and we assume Bertrand competition, the price in each sector will be set as 1 and the monopoly firms capture all of the market. We use wage as the numeraire, thus the profits of each (monopoly) firm using low technology are,

$$\pi_i^l = q_i - \frac{q_i}{\alpha_L} = a_l q_i, \tag{3}$$

where $a_l = (\alpha_l - 1) / \alpha_l$.

The production function for high technology is, $q_i = \alpha_h n_i$ where $\alpha_h > \alpha_l$. To adopt high technology the firm will incur fixed cost I. Thus the profit of the firm with high technology will be,

$$\pi_i^h = q_i - \frac{q_i}{\alpha_h} - I = a_h q_i - I, \tag{4}$$

where $a_h = \frac{\alpha_h - 1}{\alpha_h}$.

Next, we consider the incurrence of cost I as the expenditure on intermediate goods, which is very important for our analysis here. This assumption drives a wedge between aggregate income Y and gross production Q. As noted before, aggregate income Y will always be equal to total wages plus total profit. However, gross production Q here will equal to demands from both the representative consumer's consumption, which is identical to aggregate income Y, and industrialised firms' consumption on intermediate goods. Formally, we now have,

$$Q = Y + \mu I = \Pi + N + \mu I, \tag{5}$$

where μ represents the fraction of monopoly firms using the high technology.

Again, by normalising we have gross production, Q equal to production in each sector, q_i. Substituting equations (3) and (4) into (5), we have

$Q = \mu \left(a_h Q - I \right) + \left(1 - \mu \right) a_l Q + N + \mu I \Rightarrow Q = \frac{N}{1 - \mu a_h - (1-\mu) a_l}$.

Now we can solve the profit for firm i in the case of industrialisation as,

$$\pi_i^h = a_h \cdot \frac{N}{1 - \mu a_h - \left(1 - \mu \right) a_l} - I. \tag{6}$$

The profit of non-industrialisation for firm i is,

$$\pi_i^l = a_l \cdot \frac{N}{1 - \mu a_h - \left(1 - \mu \right) a_l}. \tag{7}$$

Examining equations (6) and (7), we can see that strategic complementarity are present across firms. Demand here is determined endogenously by Q which is an increasing function of μ. Intuitively, demand increases when more sectors improve their production and μ works as a multiplier. This positive externality is the focus of all previous literatures and modeled through different channels, such as profit spillover effects, labour-wage effects, or intertemporal aspects of investments in dynamic models. As noted in previous studies, through the channel of profit spillover, one industrialised firm contributes to the demand for other firms' goods if and only if they make positive profit themselves. These spillovers are not sufficient to generate the conditions for the "Big Push", and equilibrium is unique. In this paper, we focus on the channels of spillover other than profits. To do so we assume the incurred cost of industrialisation I as expenditure on intermediate products produced in other firms. Thus strategic complementarity arises in the economy through the expenditure-demand relationship across firms. With this assumption, we actually address the fact that the firm can ignore the positive externality from its investment then get away from the uniqueness result of the basic model and focus on multiple-equilibria economy.

The wedge between Q and Y results in multiple equilibria. In the model, the industrialised firm contributes to the demand for other firms' goods by raising gross production not aggregate income. That means, if some sectors in the economy industrialise, then they will be spending more on the products in the remaining sectors by at least incurring industrialisation cost, no matter whether this industrialisation increases aggregate income. These changes in composition of demand will induce the output expansion and profitable industrialisation in other sectors.

In particular, this expenditure-demand linkage can create multipliers and, when combined with nonconvexities in technology, can lead to multiple, Pareto-ranked equilibria. Suppose a single firm can not break even from investing, although it loses money, it will increase the aggregate income through its expenditure which makes the industrialisation in any other sectors become possibly profitable. Hence, even it is unprofitable for a single firm to invest, investment will be profitable if sufficiently many firms invest. Therefore firms are interested in the productive potentials of other sectors of the economy. This makes the existence of multiple equilibria possible. In the case of "Big Push", this means, at a low aggregate level of industrialisation, the equilibrium strategy played by firms will be non-industrialisation because it is individually unprofitable to industrialise. Conversely, as long as a sufficient number of other sectors industrialise, the increased demand will make industrialisation individually profitable. We illustrate this formally as below.

Assumption 3.1 *The fixed cost of industrialization I satisfies the condition* $(a_h - a_l) \cdot \frac{N}{1-a_l} < I < (a_h - a_l) \cdot \frac{N}{1-a_h}$.

The assumption implies that no individual firm can break even by industrialising alone, but it is definitely profitable if all firms in the economy industrialise. Put another way, even individually unprofitable industrialisation must have spillover effects on other sectors that make industrialisation in other sectors become possibly profitable. With this assumption, it is easy to see that we have a coordination problem and there are multiple equilibria, one with and one without industrialisation, thus there is a possibility to have "Big Push".

Proposition 3.1 *Under assumption 3.1, there exist at least two equilibria which are Pareto-ranked.*

Proof. See appendix.

This multiplicity of equilibria can be characterised by a marginal rate of μ. Let us look at the decision-rule for firm i to industrialise,

$$\pi_i^h - \pi_i^l = (a_h - a_l) \cdot \frac{N}{1 - \mu a_h - (1-\mu)\, a_l} - I > 0. \tag{8}$$

In this inequality, the entire first term is a strictly increasing function of μ, the second term is fixed and constant. It is clear that there is a marginal rate of $\hat{\mu}$ which makes,

$\pi_i^h - \pi_i^l = (a_h - a_l) \cdot \frac{N}{1-\hat{\mu}a_h-(1-\hat{\mu})a_l} - I = 0.$

The intuition here is the increased profit from increased demand which is created by $\hat{\mu}$ industrialised firms will exactly compensate the cost of industrialisation I. Thus there is a possibility of multiple equilibria. One equilibrium happens when $\mu < \hat{\mu}$. In this equilibrium, no firm incurs the cost for fear of not being able to break even and economy will become stuck in the inefficient equilibrium, no firm industrialises. Aggregate production Q is low and equal to $\Pi + N$, since no extra demand is generated. The other equilibrium happens when $\mu > \hat{\mu}$. In this equilibrium all firms expect a high level of sales resulting from simultaneous industrialisation of many sectors and are consequently happy to incur the fixed cost I to industrialise. This of course makes the expectation of industrialisation self-fulfilling. Aggregation Q is now high and equal to $\Pi + N + I$. The reason for the multiplicity of equilibria is that there is a link between a firm's investment cost and its contribution to demand for products of other sectors. Here, the firm's profit in the model is not an adequate measure of its contribution to the aggregate demand for manufactures since a second component of this contribution, the cost it incurs, is not captured by the profits.

An examination of this proposition also suggests that the economy is capable of a big push, whereby it moves from the non-industrialised equilibrium to one with industrialisation when all its sectors coordinate investments. This multiplicity of equilibrium is an very simple kind of coordination failure: if every firm industrialises then demand is high and industrialisation is optimal; if no firms accept high technology then demand is low and non-industrialisation is optimal. The possible coordinated industrialisation across firms can give rise to "Big Push" in the economics development. Next, we examine how ambiguity and ambiguity attitudes affect coordinations across economic firms and further determine the uniqueness of equilibrium.

4 The Role of Ambiguity and Expectation

In this section, we will show that ambiguity and ambiguity attitudes have predictable effects on equilibrium outcomes. Ambiguity here refers to one sector concerning industrialisation of others. The above analysis shows, with the presence of strategic complementarity, the scale of industrialisation in the whole economy will influence the return of an industrialised sector. Expecting a low aggregate level of industrialisation in which industrialisation is individually unprofitable, a sector won't industrialise; conversely, if a sector is quite optimistic in expecting a sufficient number of sectors to become industrialised then it is individually profitable to industrialise by itself. By modeling excessive optimism and pessimism with the presence of ambiguity, our results show that the anticipated scale of industrialisation could become greater under optimism or smaller under pessimism. Therefore, sufficient optimism might help create a "Big Push" in an economy, and pessimism might make an economy become stuck in an inefficient state. The ideas are illustrated as follows.

Unlike Fatas and Metrick (1997), where ambiguity relates to the cost I of the higher level technology, in our model firms are uncertain about market demand while they know perfectly the distribution of I. Since firms' expected profits depend uniquely upon expected demand under our assumptions of unit prices, wages and inelastic labour supply, we identify firms' Choquet expected value of outcomes solely depending on Choquet expected value of demand.

In the presence of ambiguity, the Choquet expected value of demand faced by a firm is,

$$CEU(Q) = \gamma \cdot \frac{N}{1-a_l} + \lambda \cdot \frac{N}{1-a_h} + (1-\gamma-\lambda)\frac{N}{1-\mu a_h-(1-\mu)a_l}. \tag{9}$$

The highest aggregate production is $Q^h = \frac{N}{1-a_h}$ when all firms are industrialised, $\mu = 1$, and the lowest aggregate production is $Q^l = \frac{N}{1-a_l}$ when all firms are non-industrialised, $\mu = 0$. The expected value of Q is $\frac{N}{1-\mu a_h-(1-\mu)a_l}$.

The firm's profit when it industrialised is, $\pi_i^h = a_h CEU(Q) - I$, and $\pi_i^l = a_l CEU(Q)$ when it is non-industrialised.

The decision rule for industrialisation now is,

$$\pi_i^h - \pi_i^l = (a_h - a_l)CEU(Q) - I > 0. \tag{10}$$

Substitute equation (9) into (10) and rearrange it, we have

$$\pi_i^h - \pi_i^l = (a_h-a_l)\cdot\gamma\cdot\frac{N}{1-a_l} + (a_h-a_l)\cdot\lambda\frac{N}{1-a_h} + (a_h-a_l)\cdot\frac{N}{1-\mu a_h-(1-\mu)a_l}\cdot(1-\lambda-\gamma) - I. \tag{11}$$

Now we show how the unique equilibrium is determined with sufficient ambiguity and prevailing ambiguity attitudes held by firms.

Proposition 4.1 *Facing sufficient ambiguity, if firms are sufficiently pessimistic, i.e.,* $\lambda \to 0, \gamma \to 1$, *an economy will maintain non-industrialisation equilibrium; if firms are extremely optimistic, i.e.,* $\lambda \to 1, \gamma \to 0$, *an economy will stay in industrialisation equilibrium.*

Proof. See appendix.

This proposition clearly shows that the first equilibrium could be privately optimal for a single firm but the economy will have the lowest aggregate production. In the second equilibrium we attain both private optimality and social optimality. The economy has the highest aggregate production.

Next we show how sufficient level of optimism and pessimism will lead to the determinacy of equilibria.

Rewriting equation (11) as below,

$$\pi_i^h - \pi_i^l$$
$$= (a_h - a_l) \cdot \left[\gamma\left(\frac{N}{1-a_l} - \frac{N}{1-\mu a_h-(1-\mu)a_l}\right) + \lambda\left(\frac{N}{1-a_h} - \frac{N}{1-\mu a_h-(1-\mu)a_l}\right) + \frac{N}{1-\mu a_h-(1-\mu)a_l}\right] - I.$$

The first term in bracket is negative and the second one is positive. The other variables in the equation are given as fixed. Now considering μ is at a marginal level of $\hat{\mu}$, if firms are more pessimistic and γ is sufficiently larger than λ, the negative term will dominate the positive one, the increased profit from industrialisation is negative. Thus, firm i won't industrialise. Conversely, if optimism prevails and λ is sufficiently large, the positive term will dominate the negative one, industrialisation will bring higher profit than non-industrialisation after cost, therefore firm i will industrialise.

Intuitively, a firm is more likely to industrialise when it is more optimistic and less likely to do so when it is more pessimistic. Why is this so? Since pessimism/optimism makes anticipated scale of industrialization smaller/larger than it actually is, which discourage/encourage firms to industrialise. This is illustrated in Figure 1. Curve $\Delta\pi$ (where $\Delta\pi = \pi^h - \pi^l$) depict the increased profit $\Delta\pi$ from industrialisation corresponding to different value of μ. Optimism/pessimism changes the perceived value of $\Delta\pi$. When firms are more optimistic, the curve $\Delta\pi$ shift leftward to $\Delta\pi^\lambda$, the anticipated scale of industrialisation now is $\hat{\mu}_2$ instead of $\hat{\mu}$, which indicates the positive value of $\Delta\pi$; when pessimism prevails, the curve $\Delta\pi$ shifts rightward to $\Delta\pi^\gamma$,the anticipated scale of industrialisation is $\hat{\mu}_1$which indicates the negative value of $\Delta\pi$.

The results might help to explain some observations in real economic growth. The catastrophic 2001 financial crisis in Argentina is possibly a good illustration. According to DeLong (2005), " *when it (the currency board) collapsed, Argentina's consolidated debt-to-GDP ratio was about 50%. That is not an unsustainable debt load. And the Argentinean government was managing to run a primary surplus. If there had been confidence in Argentina's fiscal future–confidence that no financial crisis was on the horizon–then interest rates would have been much lower, and the primary surplus would have generated only a moderate general deficit. With low interest rates, Argentina's prospects for growth would have been relatively good. With good growth prospects and a relatively moderate overall government budget deficit, there would be no reason to fear that fiscal policy is unsustainable. Only the fact that a crisis was expected pushed interest rates up to the level where investment was strangled, growth impossible, the overall budget deficit large, and a crisis inevitable".* DeLong further gave an opposite example, Brazil, a country with an equally intractable long-

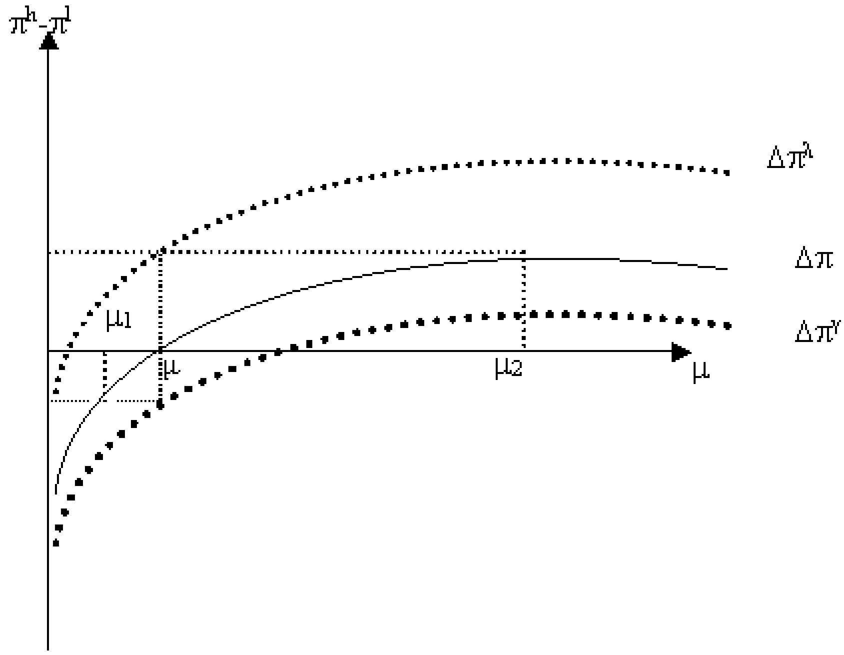

Figure 1: The curve $\Delta\pi$ depicts the increased profit from industrialisation corresponding to different values of μ. Optimism shifts the curve $\Delta\pi$ upward to $\Delta\pi^{\alpha}$, the perceived scale of industrialisation now is μ_2 instead of μ, which indicates the positive value of $\Delta\pi$ in the case of industrialisation; when pessimism prevails, the curve $\Delta\pi$ shifts downward to $\Delta\pi^{1-\alpha}$, the perceived scale of industrialisation is μ_1 which indicates the negative value of $\Delta\pi$

run problems of macroeconomic management and even worse problems of income distribution and public management, which appears to have found a good equilibrium.

5 Conclusion

In this paper, we have studied the impact of ambiguity on a "Big Push" model. We obtain some strong conclusions from modeling psychological phenomena such as excessive optimism and pessimism with the presence of ambiguity. The results of our example tell us that there exist some critical value of neo-additive capacity representing a sector's belief. For pessimism, if γ is above its critical value, no sector industrialises for lack of confidence, the effects of strategic complementarities failed to internalised thus a Pareto-inefficient outcome is the equilibrium in an economy. Conversely, if λ, representing the extent of optimism of players, is above its critical value, all players will play the Pareto-optimal strategy in equilibrium. The further analysis in a formal "Big Push" model tells us that the anticipated scale of industrialisation could be greater under optimism or smaller under pessimism. The excessive optimism or pessimism is enough to induce an unique equilibrium. Pessimism will cause a coordination failure leading to a depression, and optimism will lead to a higher equilibrium strategy level and booming economy. As well known, the fundamental idea in Keynesian macroeconomics is that changes in expectations, or animal spirits, can affect equilibrium economic activities, in terms of either level of output or employment. We believe that this paper provides a useful way to model these ideas.

The main methodological feature is the incorporation of CEU preference in the model of macroeconomic activities with presence of strategic complementarities. We argued that such an approach can be desirable in terms of real applications because many macroeconomic problems are characterised by both uncertainty and strategic interaction between the economic agents. Besides applying such an approach to the theory of economic growth, this line of work may be applied to irreversible investment problems. In this case it is our conjecture that optimistic expectation under uncertainty can solve underinvestment.

Finally, considering the potential criticism about modelling " big push" as a one-period process, it is a natural direction to extend the paper into the dynamic framework. The other promising extension in our opinion is to find empirical evidence, such as the role of confidence in the growth of China's economy. It is commonly recognised that empirical work in this area is more challenging, which, on the other hand, indicates it will be very contributive if successful.

Appendix

Proof of Proposition 3.1

Proof. For given I which satisfies assumption 3.1, we have the following two inequalities hold at the same time,

$\pi_i^h(1) - \pi_i^l(1) = (a_h - a_l) \cdot \frac{N}{1-a_h} - I > 0$

$\pi_i^h(0) - \pi_i^l(0) = (a_h - a_l) \cdot \frac{N}{1-a_l} - I < 0.$

Meanwhile,

$\pi_i^h(1)-\pi_i^h(0) = \frac{a_h \cdot N}{1-a_h} - I - \frac{a_l \cdot N}{1-a_l} = (a_h - a_l)\cdot\frac{N}{(1-a_h)(1-a_l)} - I > (a_h - a_l)\cdot\frac{N}{1-a_h} - I > 0.$

Thus, for given I, we have two equilibria which are Pareto-ranked.

Proof of Proposition 4.1.

We prove separately two pure equilibria in the economy, given the corresponding beliefs held by firms.

The decision rule is,

$\pi_i^h - \pi_i^l = (a_h - a_l)\cdot\gamma\cdot\frac{N}{1-a_l} + (a_h - a_l)\cdot\lambda\frac{N}{1-a_h} + (a_h - a_l)\cdot\frac{N}{1-\mu a_h-(1-\mu)a_l}\cdot(1-\lambda-\gamma) - I.$

1. Suppose there is sufficient ambiguity and firm i is extremely pessimistic, i.e., $\lambda \to 0, \gamma \to 1$, the profit of industrialisation or non-industrialisation of a firm will be,

$\pi_i^h = a_h \cdot \gamma\left(\frac{N}{1-a_l} - \frac{N}{1-\mu a_h-(1-\mu)a_l}\right) + \frac{N}{1-\mu a_h-(1-\mu)a_l} - I.$

Similarly, $\pi_i^l = a_l \cdot \gamma\left(\frac{N}{1-a_l} - \frac{N}{1-\mu a_h-(1-\mu)a_l}\right) + \frac{N}{1-\mu a_h-(1-\mu)a_l}.$

Thus, $\pi_i^h - \pi_i^l = (a_h - a_l)\cdot\gamma\left(\frac{N}{1-a_l} - \frac{N}{1-\mu a_h-(1-\mu)a_l}\right) + (a_h - a_l)\cdot\frac{N}{1-\mu a_h-(1-\mu)a_l} - I.$

It is easy to see that, with $\gamma \to 1$ and $\lambda \to 0$, we get $\pi_i^h - \pi_i^l = (a_h - a_l)\cdot\frac{N}{1-a_l} - I$ strictly less than 0. This implies that firm i will undoubtedly adopt non-industrialisation. If pessimism prevails in the economy, every firm will adopt non-industrialisation and we will have $\mu = 0$, which further confirm that we hold $\pi_i^h - \pi_i^l = (a_h - a_l)\cdot\frac{N}{1-a_l} - I < 0$, therefore the equilibrium is "no firm industrialise".

2. Suppose there are sufficient ambiguity and firm i is extremely optimistic, i.e., $\lambda \to 1, \gamma \to 0$, then the possible profit for firm i will be,

$\pi_i^h = a_h \cdot \lambda\left(\frac{N}{1-a_h} - \frac{N}{1-\mu a_h-(1-\mu)a_l}\right) + \frac{N}{1-\mu a_h-(1-\mu)a_l} - I$

$\pi_i^l = a_l \cdot \lambda\left(\frac{N}{1-a_h} - \frac{N}{1-\mu a_h-(1-\mu)a_l}\right) + \frac{N}{1-\mu a_h-(1-\mu)a_l}$

$\pi_i^h - \pi_i^l = (a_h - a_l)\cdot\lambda\left(\frac{N}{1-a_h} - \frac{N}{1-\mu a_h-(1-\mu)a_l}\right) + (a_h - a_l)\cdot\frac{N}{1-\mu a_h-(1-\mu)a_l} - I.$

The same analysis applies and we have $\pi_i^h - \pi_i^l = (a_h - a_l) \cdot \frac{N}{1-a_h} - I$ which is strictly greater than 0. Therefore the equilibrium in this case is that all firms invest with prevailing optimism.

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