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Pollution, Production Efficiency and Economic Growth: A Synthesis

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Abstract

Production efficiency of the firm is defined to be the maximum ratio of output to input in this paper. When a society reaches Pareto optima, this society achieves its aggregative efficiency. If the firm does not produce efficiently, transformation rate on production frontier does not make any sense because production frontier can be extended if the firm improves its own production efficiency. Therefore, production efficiency of the firm is the necessary condition of Pareto optima. Since total input is equivalent to total cost in the sense of aggregating different inputs, the concept of production efficiency of the firm can be mathematically converted into minimum cost (i.e., minimum input). When input is minimized, pollution that arises from production is minimized, ether. Thus, pollution is minimized by the efficient firm while the firm grows efficiently. This conclusion implies that government intervention is unnecessary. Consequently, the primary policy to reduce pollution would be promoting anti-pollution technology and subsiding the firm to upgrade its equipment as well as improving production efficiency of the firm rather than charging Pigovian tax and enforcing government regulation except that minimum pollution makes people not endure or environment not sustain. To summarize, this paper integrates efficiency, externality (e.g., pollution), market mechanism (e.g., supply and demand), government intervention (e.g., Pigovian tax), increasing return to scale and economic growth into growth model of the firm by which we are capable to propose pollution policy.

Keywords: externality, pollution, pigovian tax, efficiency, growth, increasing return to scale

JEL: D21, D24, D62, E24, L29.

1. Introduction

The issue of pollution, especially climate change which is caused by air pollution, attracts people's attentions all over the world in which externality, government intervention, market mechanism, production efficiency and economic growth are interwoven each other. In order to integrate those factors above into growth model of the firm, I clarify those interwoven relations briefly as follows.

1.1 Externality, Market Mechanism, Government Intervention and Production Efficiency

We breath oxygen and emit CO_2. But nobody counts CO_2 emitted by human being as air pollution. Consequently, pollution is defined to be byproducts generated from producing output and no one intends to utilize or consume those byproducts in this paper. Thus, pollution is negative externality without price. Besides, there is no monetary cost to produce pollution because all monetary cost arising from purchasing inputs is fully attributed to the monetary cost for output production. But pollution is social cost of outputs.

Pigou (1920) presented that tax can reduce negative externality and therefore government intervention improves social welfare. But Coase (1960) argued that government intervention does not absolutely makes people be optimal because externality is reciprocal so that polluters and the polluted negotiate and then reach a resolution by themselves privately if transaction cost of negotiation is reasonably low. In other words, government intervention can be replaced by market mechanism.

Baumol and Oates (1971) objected to Coase's argument because they recognized that pollution may spread over in large scale due to collective pollution (e.g., every driver contributes to air pollution and every driver is the victim of air pollution) as well as damage created by pollution is too ambiguous to estimate (e.g., Nordhaus (2017) suggested that Integrated Assessment Model (AIM) is helpful to overcome the complexity of damage caused by emission and Heal (2017) argued that discount rates among generations are an ethical issue ambiguously). Consequently, transaction cost is too high to reach a resolution by private negotiation. Bamoul and Oates (1971) also suggested that government should establish environmental standard so as to evaluate effectiveness of policy instruments for pollution abatement. Oates and Bamoul (1975) evaluated. Since government intervention is indispensable for large projects to abate pollution, Oates (2001) reviewed and considered federalism to take care the problem that states and local authorities ineffectively handle large projects to abate regional pollution.

Production efficiency (e.g., minimum pollution under given volume of output) is the corner stone of market mechanism. We can apply production efficiency to investigate the relationship between volume of pollution arising from production and the volume of output is determined by supply and demand so that we are able to propose instrument and policy to abate pollution. The controversy of government intervention versus market mechanism has not been completely analyzed by us since beginning because neither Pigou and Coase nor Bamoul and Oates concern production efficiency of the firm.

1.2 Pollution, Increasing Return to Scale and Economic Growth

Grossman and Kruger (1995) empirically studied scale effect of GDP on pollution. They found both inversed U-shaped relationship and U-shaped relationship between growth of GDP and total volume of pollution, which are named environmental Kuznets curve. There are many reasons to cause pollution abatement as GDP grows, e.g., manufacturing industries are replaced by service industries as GDP grows. Although Romer (1986) argued that production function is increasing return to scale due to the reason that GDP grows endogenously by innovative ideas, scale effect arising from increasing return to scale on pollution abatement is ignored by Grossman and Kruger. Moreover, constant return to scale is a standard assumption in empirical papers to study endogenous growth of GDP in Jones (2016), who reviewed facts of economic growth. Thus, economists have not examined scale effect from increasing return to scale on the relationship between pollution and GDP appropriately for decades.

Since the relationship between price and quantity disappears in the growth model of GDP (e.g., Solow, 1956) and the firm pursues profit so that the firm grows under the influence of supply and demand, growth model of GDP is different from growth model of the firm. Ting (2020) built a growth model of the firm on maximum return rate on capital instead maximum profit in which the firm would grow by scale due to the reason that production function is proved to be increasing return to scale rather than by adjustment in capital-labor ratio as growth model of GDP in Solow (1956) predicted. Since total volume of pollution may decline as GDP grows under increasing return to scale, the growth model of the firm capably accounts for environmental Kuznets curve. Besides, the growth model of the firm explains many economic phenomena which cannot be explained by the growth model of GDP, e.g., optimal capital structure in Ting (2012), price rigidity and wage rigidity in Ting (2017), Phillip curve in Ting (2018) and cyclical productivity, increasing return to scale, Lucas' paradox and declining labor share in Ting (2020). The principle of parsimony states that the former economic model is better than the latter models if an economic model explains more economic phenomena than other economic models do explain while all those economic models can account for a particular economic phenomenon. By the principle of parsimony, the growth model of the firm is super to the growth model of GDP for us to theoretically examine the relation between growth and pollution. In addition, microeconomic phenomena and macroeconomic phenomena are supposed to be analogous because macroeconomic phenomena are originated from aggregating microeconomic phenomena. It justifies we explain macroeconomic phenomena like large scale pollution by a microeconomic model.

1.3 Production Efficiency, Minimum Pollution under Economic Growth and Pollution Policy

In microeconomics, economists discuss production efficiency of the firm in which they focused on the situation that the firm substitutes one input factor for other input factors when the price of a particular input factor changes. They concluded that the firm produces efficiently if the rate of substitution on isoquant curve is equal to relative price of two input factors. But the concept of isoquant curve omits the key point of production efficiency of the firm: maximize outputs under given inputs.

Ting (2011) defined production efficiency to be the maximum ratio of output to input by which Ting concerned the optimal size of government in order to deal with the problem that government plans to provide good public goods (e.g., education) but there is no price for good public goods. Since input must have price because there is no free lunch, total input is conceptually equivalent to total cost in the sense of aggregating different inputs. Thus, Ting concluded that the optimal size of government is to produce quantity of good public goods at minimum average cost. This conclusion is identical to minimum cost (i.e., minimum input) under given level of output. Since both firms and governments are organization, I apply minimum input to investigate production efficiency of the firm.

It is worth noting that production efficiency of the firm is the necessary condition for Pareto optima, which is the center in neoclassical economics to analyze aggregative efficiency, because rate of transformation on production frontier is meaningless if the firm is capable to extend its own production frontier by improvement of its own production efficiency.

Since production cost of a certain quantity output regards production scale, we have to determine the optimal size of the firm under given quantity of output. Ting (2010) argued that the objective of firms is to maximize return rate on capital instead maximum profit and then built growth model of the firm on maximum return rate on capital to determine the optimal size of the firm. Minimum cost and maximum return rate on capital are dual because the firm can enhance its own return rate on capital by reducing cost if the firm does not minimize cost. Since input is minimized, it implies that pollution arising from production is minimized (i.e., social cost is minimized), too. Thus, maximum return rate on capital and minimum pollution are also dual. In other words, the firm grows efficiently under maximum return rate on capital. Since the objective of the firm and minimum pollution are harmonious, economic growth is not opposite to pollution control. Thus, government intervention is unnecessary except that minimum pollution makes environment not sustain or people not endure.

If the firm does not borrow, capital is equivalent to equity in balance sheet. If the firm borrows, then maximum return rate on capital will be replaced by maximum return rate on equity. Consequently, production efficiency of the firm is measure by three criteria. The first criterion is maximum return rate on asset, which determines the optimal size of the firm because total asset that is equal to the sum of equity plus borrowing in balance sheet represents total capital needed by the firm to run business. Second, maximize ratio of output to total asset. Third, minimize cost. Although Ting (2012) found the optimal ratio of equity to borrowing (i.e., optimal capital structure), I assume that firms do not borrow in this paper in order to simplify the growth model of the firm in this paper.

Since Pigou, Coase, Bamoul and Oates fully disregarded production efficiency of the firm under the market mechanism of supply and demand, policies of pollution abatement suggested by them are unsound and incomplete. Under production efficiency of the firm, pollution abatement policy has two choices only. One is to restrict volume of output consumed by society (e.g., Rasemy, 1927) or volume of input utilized for production (e.g., abandon power station producing elasticity by coal). In other words, trade-off between pollution and economic growth is the subsistence of this kind pollution policy. The other is to promote new technology (e.g., green energy) and subsidy firms to upgrade equipment. To improve production efficiency of the firm is prior to other pollution abatement policies if we know firms do not produce efficiently.

1.4 Organization of This Paper

The objective of this paper is to figure out sufficient conditions for production efficiency of the firm under growth by which we are able to propose effective instruments to abate pollution. Section 2 presents a growth model of the firm by which I display sufficient conditions of minimum pollution under given level of output. Further, I show how to identify the situation that the firm is in overproduction or underproduction from both the view point of social resource allocation and the view point of production efficiency of the firm. Section 3 remarks conclusions in which I propose priority for different pollution policies and I show that employment depends on output scale instead wage. This microeconomic employment theory coincides with Keynesian economics that employment fluctuation depends on the level of GDP, not wage.

2. Model

$$Q = f(K, N, I_1 \dots I_n) \tag{1}$$

$$C = wN + \sum_1^n P_i I_i \tag{2}$$

Equation (1) is production function. Where Q is quantity of output, K is capital, N is labor and I_i is intermediate good. In equation (2), C is total cost, w is wage and P_i is price of intermediate goods. It is worth noting that depreciation is the cost of capital utilization. Since depreciation is related to quantity of output, mathematic analysis will become long and cumbersome if I introduce depreciation into total cost. Thus, I intend to omit depreciation in equation (2) in order to simplify model. In other words, I regard gross return rate on capital in this paper.

The most efficient method to produce output is to maximize the ratio of output to input while total input is represented by total cost.

$$Max\ \frac{Q}{C} \tag{3}$$

$$\frac{\frac{\partial Q}{\partial I_i}C-Q\frac{\partial C}{\partial I_i}}{C^2}=\frac{\frac{\partial Q}{\partial I_i}C-QP_i}{C^2}=0\ i.e.,\frac{\frac{\partial Q}{\partial I_i}}{P_i}=\frac{Q}{C} \tag{4}$$

$$Max\ \frac{Q}{K} \tag{5}$$

$$\frac{\frac{\partial Q}{\partial K}K-Q}{K^2}=0\ i.e.,\frac{\partial Q}{\partial K}=\frac{Q}{K} \tag{6}$$

$$Max\ \frac{Q}{WN} \tag{7}$$

$$\frac{\frac{\partial Q}{\partial N}WN-QW}{W^2N^2}=0\ \ i.e.,\frac{\partial Q}{\partial N}=\frac{Q}{N} \tag{8}$$

$$Max\frac{Q}{P_iI_i} \tag{9}$$

$$\frac{\frac{\partial Q}{\partial I_i}P_iI_i-P_iQ}{(P_iI_i)^2}=0\ \ i.e.,\frac{\partial Q}{\partial I_i}=\frac{Q}{I_i} \tag{10}$$

Equation (4) means that the firm reaches production efficiency when marginal cost is equal to average cost. Equation (6), (8) and (10) imply that the firm produces efficiently when marginal product is equal to average product. Since marginal cost, average cost, marginal product and average product are all dependent on the scale of production (i.e., size of the firm), we need maximum return rate on capital to determine the optimal size of the firm by which we get

$$Max\ \pi=\frac{PQ-wN-\sum_1^n P_iI_i}{K} \tag{11}$$

$$\frac{\partial\pi}{\partial I_i}=\frac{\frac{\partial P\partial Q}{\partial Q\partial I_i}Q+P\frac{\partial Q}{\partial I_i}-P_i}{K}=0\ i.e.,P_i=P\left(1+\frac{1}{\eta}\right)\frac{\partial Q}{\partial I_i} \tag{12}$$

$$\frac{\partial\pi}{\partial N}=\frac{\left(\frac{\partial P\partial Q}{\partial Q\partial N}Q+P\frac{\partial Q}{\partial N}\right)-w}{K}=0\ i.e.,w=P(1+\frac{1}{\eta})\frac{\partial Q}{\partial N} \tag{13}$$

$$\frac{\partial\pi}{\partial K}=\frac{\left(\frac{\partial P\partial Q}{\partial Q\partial K}Q+\frac{\partial Q}{\partial K}P\right)K-(PQ-wN-\sum_1^n P_iI_i)}{K^2}=0\ i.e.,PQ=P\left(1+\frac{1}{\eta}\right)\frac{\partial Q}{\partial K}K+wN+\sum_1^n P_i\,I_i \tag{14}$$

In equation (11), P is the price of output and π is return rate on capital. Since return rate on capital is determined by quantity of capital and the difference between sales revenue and input cost in equation (11), return rate on capital is not the price for capital but the reward to capital. Equation (12) and (13) regards price of intermediate goods and price of labor (i.e., wage) respectively. By equation (6), (12), (13) and (14), we get

$$PQ=\pi K+wN+\sum_1^n P_i\,I_i=P\left(1+\frac{1}{\eta}\right)(\frac{\partial Q}{\partial K}K+\frac{\partial Q}{\partial N}N+\sum_1^n\frac{\partial Q}{\partial I_i}I_i) \tag{15}$$

$$f(tK,tN,tI_1\dots tI_n)=t^{\frac{1}{1+\frac{1}{\eta}}}f(K,N,I_1\dots I_n) \tag{16}$$

Following Ting (2020), equation (16) is derived from equation (15). Equation (16) implies that production function is increasing return to scale because price elasticity is less than minus one; otherwise sales revenue diminishes as price elasticity becomes greater than minus one so that the firm does not produce when price elasticity is greater than minus one. As absolute price elasticity increases, increasing return to scale diminishes.

By equation (4) and (12), we get

$$P_i=P\left(1+\frac{1}{\eta}\right)\frac{\partial Q}{\partial I_i}=P(1+\frac{1}{\eta})P_i\frac{Q}{C} \tag{17}$$

$$\frac{PQ}{C}=\frac{1}{1+\frac{1}{\eta}} \tag{18}$$

$$\frac{\partial\frac{(P-\varepsilon)Q}{C}}{\partial\varepsilon}=-\frac{Q}{C}<0 \tag{19}$$

The left hand side of equation (18) is the profit rate of output, which is different from return rate on capital. Equation (18) states that the firm reaches optimal size if profit rate of product is equal to rate of increasing return to scale. Following Ting (2020), we can use $P+\varepsilon$ and $P-\varepsilon$ to represent that demand curve makes a parallel shift rightward and leftward with distance ε respectively. In equation (19), $(P-\varepsilon)Q$ implies that decrease in demand during recession makes profit rate of product decline. If the firm cannot contract its fixed capital immediately, profit rate will be less than the rate of increasing return to scale before recession. Thus, the firm is oversized when profit rate is less than rate of increase return to scale during recession. Conversely, boom makes profit rate be larger than rate of increase return to scale if the firm does not expand capacity quickly enough so that the firm is undersized during the boom.

Is it possible that the firm is in oversize or undersize systematically whether business cycle occurs or not? Suppose that research and development cost of the firm is high but variable cost of the firm to produce output is low, e.g., Google, Microsoft, Youtube and firms in IT industry. In this case, return rate on capital could be high even though profit rate of product is low because output is sold in huge quantity. If we assume that variable cost approximates zero, the firm converts its objective from maximum return rate capital into maximum revenue on capital.

$$Max\ \frac{PQ}{K} \tag{20}$$

$$\frac{\partial \frac{PQ}{K}}{\partial K}=\frac{\left(\frac{\partial P \partial Q}{\partial Q \partial K}Q+P\frac{\partial Q}{\partial K}\right)K-PQ}{K^2}=0\quad i.e.,P\left(1+\frac{1}{\eta}\right)K\frac{\partial Q}{\partial K}=PQ \tag{21}$$

$$\eta=-\infty\ \ by\ \frac{\partial Q}{\partial K}=\frac{Q}{K} \tag{22}$$

Equation (22) demonstrates that the firm intends to expand until production function becomes constant return to scale. Since profit rate of product is greater one, profit rate is greater than rate of constant return to scale, which is equal to one. Thus, the firm is undersized systematically from the view point of production efficiency of the firm under this circumstance. In other words, the firm will grow as large as possible so that monopoly is indispensible. This conclusion is consistent with what happens in IT industry exactly. But these firms in IT industry are oversized from the view point of social resource allocation because monopoly causes negative externality on social welfare.

Since financial industry provides service with high profit rate and low variable cost so that financial industry is always in undersize, there are giant financial firms and there are too many financial firms to exist in financial industry. Besides, most financial service is to manage assets instead GDP production. It seems to be appropriate that government charges cooperation tax on financial firms and Pigovian tax on resources used by financial industry and IT industry in order to reallocate resources.

Consider another case that variable cost is high but cost of research and development is low, e.g., factory of apparel. Since apparel factory is labor intensive, it is reasonable to assume that the production function of apparel factory approximates to constant return to scale. Profit rate of apparel is greater than one even profit rate of apparel is low. Thus, the apparel factory is undersized systematically from the view point of production efficiency of the firm. It explains why apparel companies in labor intensive and underdeveloped country keep growing and apparel companies in developed countries not only concentrate on new design and new material for apparel but also outsource production of apparel to underdeveloped countries because there is no increasing return on scale arising from producing apparel but there is increasing return to scale from new ideas about apparel in developed country as Romer (1986) emphasized.

When profit rate is less than rate of increasing return to scale under production efficiency of the firm, it implies that the firm is oversized due to either decrease in market demand for its product or domination of increase in production cost over decrease in production cost arising from increasing return to scale of whole economy. For example, apparel industry in a labor intensive country starts to decay if wage rises more than cost reduction arising from increasing return to scale of whole economy so that profit rate of product becomes less than one (i.e., the firm loses money). Equation (22) indicates the rise and fall of industries in a country.

3. Conclusions

Since we produce because we consume, consumption is the ultimate source of negative externality like pollution. Thus, it is impossible to reduce negative externality without reduction in consumption if the firm produces efficiently and there is no technology progress so that the substance of large scale negative externality abatement (e.g., global warming) under production efficiency of the firm is the tradeoff between consumption and abatement of negative externality. To improve inefficiency of production is an instrument for policy to reduce negative externality, which is prior to Pigovian tax and government regulation because they hurt consumer welfare. Besides, government should keep an eye on subsidy to upgrade equipment and promotion of new technology in order to abate pollution even the firm produces efficiently. For example, government should subsidize solar power to increase demand for solar power so that increasing return to scale and cost down accelerate.

Suppose that the firm utilizes a particular intermediate good inefficiently from the view point of production efficiency of the firm or social resources allocation. For example, Bitcoin utilizes electricity to mine Bitcoin because Bitcoin mining generates revenue. But the substance of Bitcoin is neither physical goods nor service included by GDP but purchasing power. Production function of Bitcoin mining is decreasing return to scale because output of Bitcoin mining is cut in half every 210,000 blocks mined or, about every four years. It is worth noting that decreasing return to scale requires that price elasticity should be positive (i.e., price and quantity rise together or fall together) which is a standard phenomenon in speculation e.g., stock market.

Although production function of Bitcoin is decreasing return to scale, both profit rate and return rate on capital of Bitcoin mining industry are high because the price of Bitcoin rises (i.e., demand for Bitcoin increases) so huge as to overwhelm decreasing return to scale. Since profit rate of Bitcoin mining industry is greater than the rate of decreasing return rate to scale, Bitcoin mining industry keeps expanding from the view of production efficiency of the firm. But it is inappropriate that production function of increasing return to scale in GDP production is replaced by production function of decreasing return to scale in Bitcoin mining. Thus, Bitcoin mining is overproduced from the view point that Bitcoin industry is undersize systematically with decreasing return to scale as well as Bitcoin miners substitute resources of non-GDP production for resources of GDP production. Therefore, it is appropriate that government charges Pigovian tax on inefficient utilization of electricity in Bitccoin mining industry.

Suppose government plan to charge pigovian tax on electricity in order to abate air pollution arising from power station while all other intermediate goods are utilized efficiently and households consume electricity efficiently. In this case, the right policy is to charge electricity Pigovian tax on firms like Bitcoin mining industry, who utilizes electricity as intermediate goods inefficiently, prior to all electricity users. This conclusion is against Diamond and Mirreele (1971) who argued that optimal tax policy should charge final goods only. Since Diamod and Mireele considered Pareto optima (i.e., production efficiency in the sense of aggregation) but ignored production efficiency of the firm, the conclusion of Diamod and Mireele (1971) is incomplete and unsound. Besides, Ramsey (1927) showed that government should charge tax on all consumption goods proportionally to its price elasticity instead government charges tax on a particular consumption good like Bitcoin. Since Ramsey (1927) did not consider production efficiency of the firm and differences in social cost of pollution among consumption goods, charging Pigovian tax on a particular consumption good is supposed to be acceptable.

Finally, I would like to write a short note on demand for intermediate goods, especially labor. Equation (23) and (30) in Ting (2020) represents how growth (i.e., rightward shift in demand curve) affects employment and wage respectively. Thus, $\frac{\partial N}{\partial W} > 0$, which is derived from $\frac{\partial N}{\partial c} < 0$ in equation (23) and $\frac{\partial W}{\partial c} < 0$ in equation (30) where c is the distance of demand curve shifting, is opposite to substitution effect between labor and capital caused by change in wage. This conclusion is reinforced by empirical evidences that both employment and wage increase during growth. Otherwise $\frac{\partial N}{\partial W} < 0$ should be evident during boom if substitution effect dominates scale effect. In other words, wage has no effect on the fluctuation of level of employment during business cycle because business cycle is the phenomenon of fluctuation in scale of output, not a phenomenon of adjustment in capital-labor ratio. In addition, we can apply scale effect to all intermediate goods (i.e., demand for intermediate goods depends on the level of output, not the price of intermediate goods) because both quantity of any intermediate good and its price rise and fall simultaneously as equation (23) and (30) predict.

Solow (1956, footnote 3) stated “The complete set of three equations consists of (3), (4) and $\frac{\partial F(K,L)}{\partial L} = w$”.

Comparing with equation (13), Solow's wage equation missed both demand, represented by price elasticity, and price of output so that Solow had never realized that production function should be increasing return to scale instead constant return to scale. Besides, Solow did not introduce wage into his model formally; otherwise Solow should display an extra equation in his paper to show that wage and profit rate of product will reach new equilibrium after capital-labor ratio adjusts in order to respond to business cycle. Further, Solow (1956, P.71) wrote "Note on passing that with constant return to scale the marginal productivities depend on the capital-labor ratio r, and not on any scale quantity." Since Solow never considered scale effect on marginal productivity (e.g., marginal productivity increases as output grows if production function is increasing return to scale), Solow did not distinguish change in employment caused by change in wage (i.e., substitution effect arising from change in capital-labor ratio) from change in employment caused by change in output level (i.e., scale effect coming from change in level of output). Solow (1956), who argued that changes in the ratio of capital to labor can bring employment back to the level before recession, is wrong.

Classical school argued that unemployment exists due to the reason that wage is higher than equilibrium wage so that reduction in wage is the only prescription to cure unemployment problem effectively. Certainly, there is unemployment if market wage is higher than equilibrium wage under the circumstance that both aggregate labor demand curve and aggregate labor supply curve are given. Under this circumstance, increase in unemployment accompanies with rising wage absolutely. But this theoretical prediction is against facts we have observed for hundred years that both employment and wage not only rise but also fall together simultaneously. Ting (2012) explained the phenomenon of decrease in employment with decrease in wage (i.e., $\frac{\partial N}{\partial W} > 0$) by the leftward shifting of labor demand curve due to decrease in the level of output with given labor supply curve because demand for labor is derived demand, derived from the level of output, in Ting (2012). Notice that the level of output is the third variable to determine volume of employment in the two dimensions (wage and labor) diagram so that the change in level of output makes labor demand curve shift in two dimension diagram.

Similarly, classical school attributed general glut to price rigidity because classical school argued that supply is greater than demand if and only if market price is greater than equilibrium price under given supply curve and demand curve. Thus, the only valid prescription to erase oversupply of goods is to make price fall. Keynes also introduced wage rigidity and price rigidity into General Theory to explain inertia of recession. But they all ignored the possibility that general glut is caused by leftward shifting in demand curve by which excess supply of good would associate with decrease in market price rather than increase in excess supply of goods accompanies with increase in market price which is predicted by the model of classical school. As Keynes proposed, increase in demand like fiscal policy is a valid prescription to cure excess supply of goods during recession. Besides, Ting (2017) demonstrated that firms shrink their size (i.e., supply curve shifts leftward) when demand declines (i.e., demand curve shifts leftward) during recession so that there are not only perfect price rigidity but also decrease in output sold in market if both supply curve and demand curve shift toward the same direction proportionally. Ting's argument and the note above that shifting in supply curve and demand curve is an essential characteristic in macroeconomic analysis are the micro foundation for the unemployment theory of Keynes and the income determination theory of Keynesian economics.

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