Internal firm structure, external market conditions and competitive dynamics

Jing Chen and Sungchul Choi*

School of Business
University of Northern British Columbia
Prince George, BC V2N 4Z9, Canada
Fax: 1–250–960–5544
E-mail: chenj@unbc.ca
E-mail: schoi@unbc.ca
*Corresponding author

Abstract: To investigate the competitive dynamics of dominant-fringe firm competition, this paper considers a new analytical theory of production and competition, which incorporates the relationships amongst fixed costs, variable costs, market uncertainty and product value. In particular, we examine the role of the production cost in the dynamic dominant-fringe firm relationship.

Keywords: cost structure; market uncertainty; dominant-fringe competition; dynamics.

Biographical notes: Jing Chen is an Assistant Professor at the School of Business of the University of Northern British Columbia, Canada. He has developed a unified economic theory of life and human societies from fundamental physical laws. A systematic introduction of the theory was presented in his 2005 book, *The Physical Foundation of Economics: An Analytical Thermodynamic Theory*. This new economic theory consists of three parts: theory of production, theory of mind and theory of value. This paper is an application of production theory. More information about his ideas can be found at his website, http://web.unbc.ca/~chenj/.

Sungchul Choi is an Assistant Professor at the School of Business of the University of Northern British Columbia, Canada. He received his PhD in Marketing from the University of Alberta. His research focus is on promotions and channels of distribution, fairness in competitive markets, pricing and community sustainability.

1 Introduction

In general, market competition among different firms is affected by two factors: "detection lags and asymmetries between firms. The consequences of the first factor can be obtained easily from any of the dynamic-game approaches …. Unfortunately, efforts

to formulate the second factor have not been as successful" (Tirole 1988, p.240). While much effort has been made to model the relation between internal organisation structure and external market environment, a lack of analytical theory regarding firms is an obstacle to an integrated understanding of the interaction between firm structures and market competition. Dominant-fringe firm competition is an example of incorporating the influence of structural asymmetry between firms on market competition that we will explore in detail.

Dominant-fringe firm relationship has been increasingly studied due to the growing dominance of powerful retailers in recent years as well as salient characteristics of asymmetric power and price leadership. Previous studies mostly build on Scherer and Ross (1990), dating back to Forchheimer (1908). Although this well established model explains how price and market shares are determined when a single firm dominates the homogeneous product industry, the model is not completely satisfactory because it incorporates strong assumptions as follows. First, a factor contributing to the rise of a dominant firm is its lower production cost resulting from economies of scale. However, most research does not provide the role of the production cost structure in the dominant-fringe firm relationship by assuming the same production costs of the dominant and fringe firms. Although a few recent studies (Fruchter and Messinger, 2003; Chen, 2003) incorporate different marginal costs to the dominant and fringe firms, they do not explain why dominant firms enjoy lower marginal costs except the vague notion of 'efficiency'. This could not explain why fringe firms cannot learn to become more efficient. In the current literature, the cost structures of dominant and fringe firms are fixed (Rassenti and Wilson, 2004). This could not explain why, from time to time, dominant firms cannot compete effectively against small firms, especially in more uncertain periods. Second, most current literature assumes non-strategic competitive fringe in which the fringe takes the market price as given. When empirical evidences show that fringe firms may actively engage in price competition, it cannot be precisely modelled. It was observed that the existence of small firms in local markets is often associated with high level of price volatility while markets served only by large firms exhibit price stability. However, in the current theory, the structural difference between large and small firms is not incorporated into the understanding of market competition (Eckert, 2003).

The current paper develops a more general analysis of the dynamic dominant-fringe firm competition and offers a clear understanding of how market competition is related to the firm structure. In particular, we examine effects of market uncertainty, firm size, market entry, and strategic fringe on the dominant-fringe firm relationship. Toward this, we apply a new analytical formula of variable cost as the function of fixed cost, market uncertainty and product value (Chen, 2005). This analytical formula enables us to make a systematic comparison of performance of different types of strategy under different kinds of market conditions.

In this work, we show that in general, low marginal costs are achieved through higher fixed cost. Moreover, cost structure is significantly influenced by market uncertainty. From this analytical theory, it can be computed that as fixed costs increase, variable costs decrease rapidly in a low market uncertainty environment and decrease slowly in a high market uncertainty environment. The variable costs of small companies, as low fixed cost systems, are not very sensitive to the level of market uncertainty. The variable costs of large companies, as higher fixed cost systems, increase rapidly as

market uncertainty increases. Thus, small fringe companies tend to adopt flexible marketing strategies to gain market shares while large dominant companies prefer to maintain stable market conditions.

In addition, the evolution of the market environment affects dominant-fringe firm competition over time. In particular, when market uncertainty is high, it creates opportunities of entry for small or new firms, because variable costs are high for large firms in highly uncertain environment. Similarly, incumbent fringe firms may be squeezed out by the dominant firm when the market uncertainty comes down. This theory provides a natural understanding for some well documented, yet inadequately modelled, patterns in market competition.

This paper is structured as follows: Section 2 reproduces the analytical theory of production and competition of firms for the completeness of exposition (Chen, 2005). Section 3 applies the theory to understand patterns of competitive dynamics among different types of firms in the Canadian retail gasoline market. Section 4 explains how our theory provides practical guidance for different kinds of firms to adopt proper strategies to cope with various market conditions. The concluding section summarises major findings and delineates future research areas.

2   An analytical theory of production and competition of firms

Suppose S represents the economic value of a commodity, r, the discount rate, and σ, the rate of market uncertainty. The process of S can be represented by the lognormal process:

$$\frac{dS}{S} = rdt + \sigma dz. \tag{1}$$

A firm produces the commodity. The production of the commodity involves fixed cost, K, and variable cost, C, which is a function of S, the value of the commodity. From the Feymann-Kac formula, (Øksendal, 1998, p.135) the variable cost, C, as a function of S, satisfies the following equation:

$$\frac{\partial C}{\partial t} = rS\frac{\partial C}{\partial S} + \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 C}{\partial S^2} - rC \tag{2}$$

with the initial condition:

$$C(S,0) = f(S). \tag{3}$$

To determine $f(S)$, we perform a thought experiment about a project with a duration that is infinitesimally small. When the duration of a project is sufficiently small, it has only enough time to produce one unit of product. In this situation, if the fixed cost is lower than the value of the product, the variable cost should be the difference between the value of the product and the fixed cost to avoid arbitrage opportunity. If the fixed cost is higher than the value of the product, there should be no extra variable cost needed for this product. Mathematically, the initial condition for the variable cost is the following:

$$C(S,0) = \max(S - K, 0) \tag{4}$$

where S is the value of the commodity and K is the fixed cost of a project. When the duration of a project is T, solving Equation (2) with the initial condition in Equation (4) yields the following solution:

$$C = SN(d_1) - Ke^{-rT}N(d_2) \tag{5}$$

where:

$$d_1 = \frac{\ln\left(\dfrac{S}{K}\right) + \left(r + \dfrac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}$$

$$d_2 = \frac{\ln\left(\dfrac{S}{K}\right) + \left(r - \dfrac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}.$$

The function $N(x)$ is the cumulative probability distribution function for a standardised normal random variable. Equation (5) takes the same form as the well-known Black-Scholes (1973) formula for European call options.

Suppose the volume of output during the project life is Q, which is bound by production capacity or market size. We assume the present value of the product to be S and variable cost to be C during the project life. Then the total present value of the product and the total cost of production are:

$$SQ \text{ and } CQ + K \tag{6}$$

respectively. The return of this project can be represented by:

$$\ln\left(\frac{SQ}{CQ + K}\right) \tag{7}$$

and the net present value of the project is:

$$QS - (QC + K) = Q(S - C) - K. \tag{8}$$

The above analytical theory enables us to make quantitative calculations for returns on different projects in different kinds of environments. First, we examine the relation between fixed cost and variable cost at different levels of market uncertainty. Calculating variable costs from Equation (5), we find that, as fixed costs are increased, variable costs decrease rapidly in a low market uncertainty environment and change very little in a high market uncertainty environment. Put another way, high fixed cost systems are very sensitive to changes in the market uncertainty level while low fixed cost systems are not. This is illustrated in Figure 1.

Next we discuss the returns of investment on different projects with respect to the volume of output. Figure 2 is the graphic representation of Equation (7) for different levels of fixed costs. In general, higher fixed cost projects need higher output volume to break even. At the same time, higher fixed cost projects, which have lower variable costs in production, earn higher rates of return in large markets.

Figure 1   Level of uncertainty and variable cost (see online version for colours)
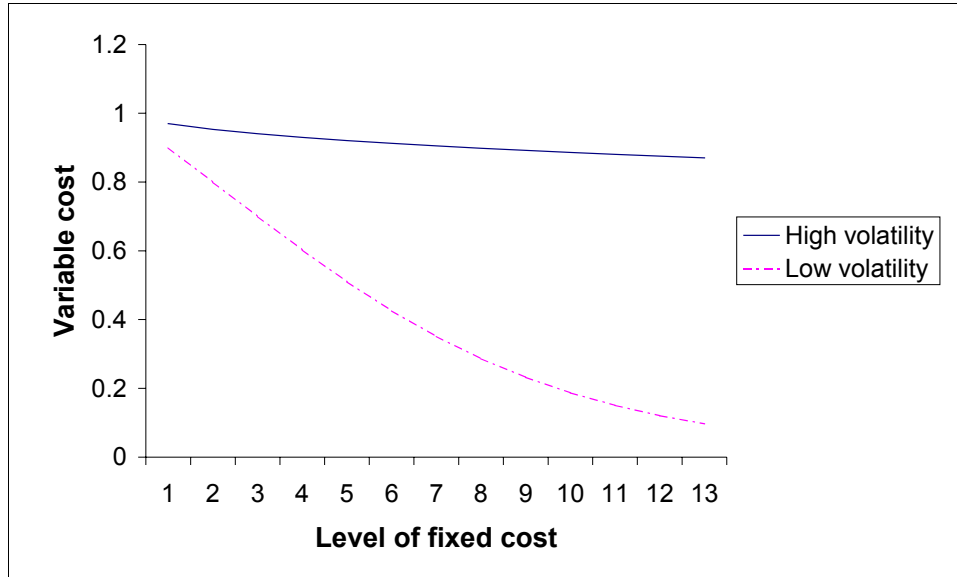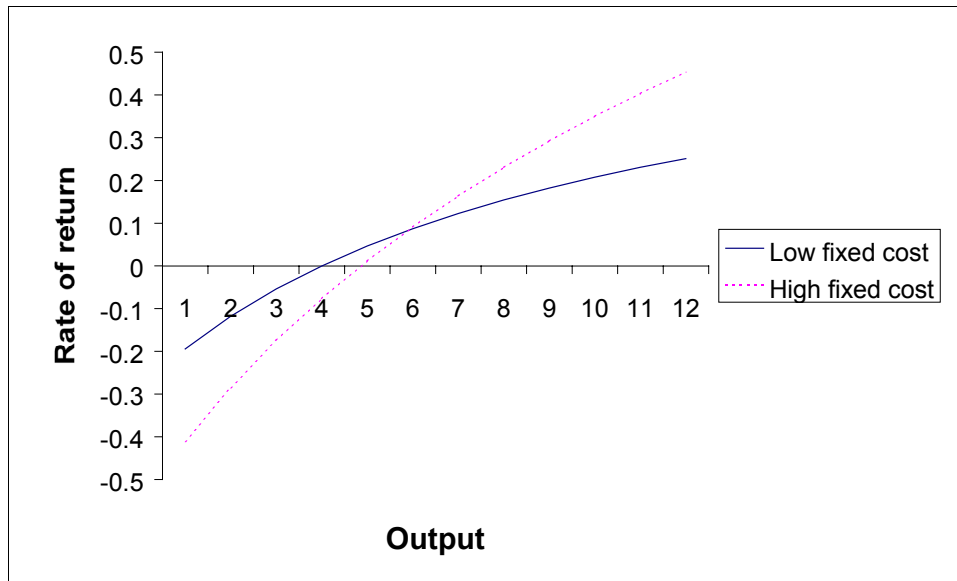

Figure 2   Output and return with different levels of fixed costs (see online version for colours)

From the above discussion the level of fixed investment in a project depends on the expectation of the level of uncertainty of production technology and the size of the market. When the outlook is stable and market size is large, projects with high fixed investment earn higher rates of return. When the outlook is uncertain or market size is small, projects with low fixed cost break even easier.

A project will last for a period of time. During that period of time, market condition may change, rendering projects designed for highest return under original estimation of future market condition non-optimal. Suppose, for a certain product, the initial estimation of uncertainty is 55% per annum and the market size is 100. Assume product value to be 1, discount rate to be 8% per annum and the project will last for 25 years. From Equation (7), a project will earn the highest rate of return when the fixed investment is 9.0. After the project has been built, however, the new estimation of market uncertainty becomes 50% per annum and the market size becomes 150. With this new estimation, calculated from Equation (7), a project with the fixed cost of 20.2 will earn the highest rate of return. But should we abandon the existing project and build a new project with higher fixed cost?

We can perform a new calculation. If we continue the existing project, the rate of return from the project, calculated from Equation (7), will be 19%. If we abandon the existing project and start a new project with the fixed cost of 20.2, adding the sunken cost of 9.0 from the old project, the rate of return will be 15%, which is lower than the continuation from the existing project. The above calculation shows that future strategies are conditioned by past investment. Although a newer design for the project offers a higher rate of return than the existing one, it may not be economical to build new projects because of the sunken cost from earlier investment.

There are often many firms operating in the same industry. The dynamics of competition among different types of firms is a research topic that has attracted great interest (Rassenti and Wilson, 2004). In the following, we will use a numerical example to show how dominant and fringe firms share a common product market. Large firms often serve the market segment with large and stable customers and leave small and unstable customers to smaller firms. Suppose the total market size of a product is 400 million, of which 300 million is stable with their uncertainty level at 45% per annum and the other 100 million is more volatile, with an uncertainty level of 65% per annum. Suppose there are two firms in the market. One is the dominant firm with a level of fixed assets at 40 million and the other is the fringe firm with a level of fixed assets at 5 million. Assume the unit value of the product is 1 million, discount rate is 8%, and the facilities last 20 years. If the dominant firm only serves the 300 million stable market segment and leave the 100 million volatile market segment to the fringe firm. From Equation (8), the profit for the dominant firm is 163.4 million and the profit for the fringe firm is 9.7 million. If the dominant firm decides to serve the whole market, because of the need to cater the more volatile market segment, its internal operation has to adapt according to the rhythm of the high volatility. Hence the level of uncertainty for the whole firm will be adjusted to a higher level, one that is close to 65%, the level of uncertainty of the volatile market segment. With this level of uncertainty, from Equation (8), the profit of the dominant firm, while serving the whole market, is only 100.7 million, which is less than the 163.4 million when the dominant firm was only serving the large and stable market segment. At the same time, it is difficult for the fringe firm, because of its higher level of variable costs, to compete with dominant firm in the large and stable market segment. This is why dominant firms and fringe firms often coexist in the same market.

From the above discussion, firms with different levels of fixed costs are affected by market environment in different ways. This asymmetry determined that large and small firms will adopt different production and marketing strategies. In the next section we will

show that the new theory of production and competition offers a clear understanding of the market patterns that have not been adequately modelled by the existing theories. For simplicity, we will base our analysis on a recent work on gasoline retail price movement in the Canadian market (Eckert, 2003).

3   Firm types, price competition and market environment

It was observed that the existence of small independent firms in local markets is often associated with high levels of price volatility while markets served only by major brands exhibit price stability. This pattern has not been precisely modelled in existing theories. For example, in Eckert (2003) small and big firms "are used here to refer to presence in the downstream only, and will not be reflective of capacity constraints" (p.160, note 14). Therefore the existing theory only models how the size of local market share affects firm behaviour. This is not related to the observed pattern that the existence of independent firms causes price volatility. As Eckert (2003) observed, one shortcoming of the current theories is that marginal costs are constant in their models. Since no extra insights are derived from the cost structure of firms, production is often assumed to be costless for simplicity. In our theory, the influence of fixed cost and uncertainty on marginal cost is explicitly represented by an analytical function, which makes the model more realistic. From Figure 1, high fixed asset entities, the brand name firms, are more sensitive to uncertainty and prefer stable prices. In a market dominated by large firms, they will naturally collude with each other to maintain high price. Small independent firms, as low fixed asset entities, are more willing to adopt opportunistic behaviours. In a market where large and small firms coexist, the small firms, being very flexible, tend to compete aggressively to gain market share. Their aggression causes low price levels and high price uncertainty. Our theory does not require the assumption of simultaneous decision making or alternative decision making of competing firms, as it does in dynamic game theory. This is because in our theory, a project last for a long period of time and hence long term effect has to be considered.

In the following we will use an example to further illustrate the pricing strategies of different firms. Suppose there are two gas stations, one from a small independent firm and the other from a large branded firm, in two cities. Each gas station sells 30 unit of gasoline daily at a gasoline price of 1. The large firm has a fixed cost of five and small firm has a fixed cost of two. We further assume the discount rate is 12% per year and the durations of the fixed assets of both firms are 15 years. If the usual uncertainty rate is 35%, the marginal cost for two gas stations are 0.748911 and 0.549137 respectively, calculated from Equation (5). If each gas station decided to start an aggressive price competition to increase daily volume to 50, the uncertainty rate will increase to 55%. From Equation (5), marginal cost for both gas stations will become 0.846708 and 0.739794 respectively. The profit difference of the gas stations from the small independent firm will be:

$$50(1 - 0.846708) - 30(1 - 0.748911) = 0.131896.$$

While the profit difference of the gas station from the large firm will be:

$$50(1 - 0.739794) - 30(1 - 0.549137) = -0.51558.$$

From the computation, we can see that gas stations from small, independent firms will benefit from aggressive pricing competition while large firms will not. The above calculation is consistent with the empirical patterns: large firms often engage in price collusion while small firms are more aggressive in price competition.

The existing theories do not offer an understanding of the market conditions under which small, independent firms are likely to persist and what kind of market will be dominated by established major brands. In Table 2 of Eckert (2003), which is reproduced here as Table 1, cities were listed according to the level of gasoline price volatility and it was observed that price volatility was highly associated with the existence of small independent firms.

Table 1   Some Canadian cities listed according to the gasoline price volatility

Toronto
London
Windsor
Sudbury
Montreal
Ottawa
Calgary
Edmonton
Quebec City
Sault Ste. Marie
Thunder bay
North Bay
Vancouver
Regina
Halifax
Timmins
St. John
Winnipeg
St. John's

Source: Eckert (2003)

However, no reason was given why some cities have more small independent firms than others. From our theory, small firms thrive in volatile environments. Toronto and other Ontario communities have experienced very dynamic changes in population, housing prices and economic activities, which foster a favourable environment for small firms. Atlantic and prairie cities are stable and stagnant, which make it difficult for small firms to get established. This is consistent with patterns in ecological systems where low fixed cost r strategists thrive in disturbed environments and high fixed cost, K strategists, dominate in stable environments (Colinvaux, 1978).

4   Firm strategies under different market conditions

From earlier discussion, strategies under which a company may adopt profitably are seriously constrained by internal and external environment. However, this does not mean that firms cannot benefit from deep understanding of strategic dynamics. On the contrary, a good understanding of these constraints will help firms realise potential opportunities or avoid costly losses systematically. In the following, we will analyse how firms of different sizes may adopt different strategies under different market sizes and different levels of market uncertainty.

For example, it is often assumed that a growth industry offers opportunities for new entrants. From our theory, it is not the growth itself, but the change of industries that offers opportunities for new comers. Take the auto industry for example. At one time, there were over three hundred automakers in the USA. Although the volume of car production has continue to increase over time, the number of US automakers dropped to three long time ago (Mazzucato, 2000). From Figures 1–2, when an industry matures with low uncertainty, the increase of market size will further enhance the competitive advantage of large firms and cause the market to consolidate, which often reduces the number of viable players. Since growth and change of an industry frequently come together, we often attribute the opportunities of new entrants to the growth of an industry. But a more precise understanding, which separates market uncertainty from the growth of market size, will help us assess opportunities better. For example, when the standard of an industry emerges, the growth of that industry will still be strong, but little change will be seen. In the new environment of large market size and low uncertainty, small firms should either join the dominant firms or become niche players in specialised areas to avoid direct competition from dominant firms. Potential new entrants should not hastily join the foray simply because the industry is still growing.

Business activities often involve trial and error. But understanding constraints to business activities will help firms to design strategic actions more effectively. Large firms' inherent stable structure is not very compatible with innovative ideas. Therefore, large firms often leave the early stage R&D, which is very volatile and unpredictable, to small firms. For example, large pharmaceutical firms often buy preliminary research results from small research firms instead of generating them in house. This helps insulate large firms from volatile early R&D activities.

Large firms often delay the entry to promising but volatile new markets because their high level of resource bases make them more vulnerable to legal and reputational damage. For example, a small firm with few tangible assets is rarely worth the effort of lawyers, while a large and wealthy firm, such as Microsoft, is constantly under scrutiny by professionals for possible legal action. This slowness of large firms, to enter new markets, creates opportunities for small firms. Despite the lack of financial resources, compared to established large firms, small firms account for a disproportionately high share of innovative activity (Acs and Audretsch, 1990).

Although large firms are slow in entering new markets, they often have the ability to recapture the markets that turn out to be large. From Figure 2, large firms with high fixed costs, because of their low marginal costs, often dominate large markets. Take Microsoft as an example. From time to time, Microsoft develops its own application software to replace popular application software from other vendors, such as Word (WordPerfect), Excel (Lotus 123) and Internet Explorer (Netscape). Because Microsoft bundles application software with its operating system in distribution, its variable cost in

distributing application software is lower than other software makers who have to market their products separately. This ability, for high fixed cost large firms to recapture maturing large markets, is consistent with patterns in ecological systems where high fixed cost K systems will eventually replace low fixed cost r systems when environmental disturbances subside (Colinvaux, 1978).

From the above discussion, we learn that market entry and profit opportunities of different firms are seriously conditioned by market environment. It is often difficult for small firms to operate in a large and mature market and for large firms to navigate in a new and volatile market. Large firms, with low variable costs, generally concentrate in large and established markets to exploit economies of scale. Small firms, with high variable costs, should avoid standardised large markets where dominant firms have the advantage of low variable cost. They should settle in niche markets of small sizes or be active in volatile markets, which might become large enough to more effectively compete against the large firms when the market grows. However, this does not mean that it is impossible for firms to reap potential opportunities that seem to inconsistent with their firm structures.

When a large and well established firm does foresee an attractive but highly uncertain new business line, it is often optimal to spin off the unit into a separate entity instead of keeping it internally. This will reduce the conflict between the demand for stability in a large organisation and the requirement of flexibility for innovative businesses. When small new firms sense that the market they work in will expand tremendously in size, they should try to expand rapidly with the help of financial instruments (*e.g.*, by merging their operations, through merges or takeovers) to preempt the entry of other large firms with deep pockets. For example, many innovative firms that create new large market demands, such as amazon.com, skilfully use the proceeds from financial markets to grow rapidly into large firms.

5   Conclusion

This paper introduces a new analytical theory, for the firm to examine competitive dynamics of the dominant-fringe firm competition, in determining the relationship between internal firm structure of production costs and external market condition of uncertainty. Within an example of the Canadian gasoline retail market, we demonstrate the influence of fixed cost and uncertainty on marginal cost. In particular, we find that small independent gas stations benefit from aggressive pricing competition while dominant firms do not. In addition, we answer the question of why some cities have more small independent firms than others. The new framework also suggests that market entry and profit opportunities of firms facing different cost structure are seriously constrained by the external market environment. Thus, the analytical theory explains under what conditions the dominant firm cannot take advantage of economies of scale.

The assumption of constant marginal costs is a major shortcoming of current literature of price competition and limits a clear understanding of competitive dynamics between firms. By investigating dynamic relationships between internal firm structure and the external market environment, this paper offers a clear understanding of how market competition is related to firm structure.

Overall, this paper suggests an important research avenue that incorporates the relationship between internal and external environments into theoretical analyses and empirical investigations for dominant-fringe relationships, pricing, and other marketing competition. In addition, we stress that our paper involves a dominant-fringe structure considering uncertainty, firm size, market entry, and strategic fringe. A direction for future research is to include other market variables. For instance, the extant models of dominant-fringe firm relationship mostly focus on the homogeneous product market. In reality, however, the dominant firm may have a significant quality advantage due to efficiency and innovation. Accordingly, it is of interest to examine the role of product differentiation in the dominant-fringe firm competition.

Acknowledgement

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