Flexibility of wages
and macroeconomic instability
in an agent-based computational model
with endogenous money

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We present a model of a dynamic and complex economy in which the creation and the destruction of money result from interactions between multiple and heterogeneous agents. In the baseline scenario, we observe the stabilization of the income distribution between wages and profits. We then alter the model by increasing the flexibility of wages. This change leads to the formation of a deflationary spiral. Aggregate activity decreases and the unemployment increases. The macroeconomic stability of the model is affected and eventually a systemic crisis arises. Finally, we show that the introduction of a minimum wage would have allowed the aggregate demand to be boosted and to avoid this crisis.

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1 Introduction

In the General Theory, Keynes insists on the necessity of taking into account 'the complexities and interdependencies of the real world' (Keynes, 1936). He strongly criticizes the methods which 'expressly assume strict independence between the factors involved'. For Keynes, it is 'the nature of economic thinking' to 'allow, as well as we can, for the probable interactions of the factors amongst themselves.'

Among the complex problems approached by Keynes on the General Theory, we find the question of the effects of a decrease in nominal wages on the level of unemployment, prices, and the equilibrium of the whole system. Keynes criticizes the view according to which unemployment would find its explanation in the existence of 'frictional resistances' preventing wages to adapt to the aggregate demand of labor. For him, one can't argue by supposing fixed the global effective demand:

> (. . .) whilst no one would wish to deny the proposition that a reduction in money-wages accompanied by the same aggregate effective demand as before will be associated with an increase in employment, the precise question at issue is whether the reduction in money-wages will or will not be accompanied by the same aggregate effective demand as before measured in money, or, at any rate, by an aggregate effective demand which is not reduced in full proportion to the reduction in money-wages (. . .) (Keynes, 1936)

According to Keynes, the effects of a fall in nominal wages are not limited to the labor market. Because the level of the effective demand can be modified, these effects can extend to prices of goods, and affect the stability of the whole economy.

> For if competition between unemployed workers always led to a very great reduction of the money-wage, there would be a violent instability in the price-level. Moreover, there might be no position of stable equilibrium except in conditions consistent with full employment (Keynes, 1936)

Keynes paints the picture of the economy as a system in which the interactions between elements (households and firms) are real and monetary simultaneously. Because in this system the interdependences are multiple, we cannot study the effects of the variation of one of its elements without examining the effects on other elements and possibility of positive or negative feedback. The representation of the economy that Keynes gives us corresponds to what we call a complex system today.

A complex system is a system composed of units interacting according to simple rules, but which exhibits emergent properties, that is, macroscopic properties arising from the interactions of the units that are not properties of the individual units themselves (Tesfatsion 2006, Farmer and al. 2009a). If we

consider economic systems as complex systems, then agent-based modeling constitutes an essential tool to investigate their properties and study their dynamics (Arthur 2006, Leijonhufvud 2006, Howitt 2008).

In section 2, we describe the construction of an agent-based model of a monetary economy of production. In this model, real and monetary quantities are strictly distinguished. Money is endogenous: its flux and its reflux are determined by the interactions between the agents composing the system.

In section 3, we describe the behavior of the model. We observe the emergence of macroeconomic regularities characterized by the stability of the distribution of total income between wages and profits.

In section 4, we alter the model by increasing the flexibility of wages. We then observe a fall in aggregate demand. Firms react cutting prices and production. The development of the deflationary spiral leads to a systematic crisis. Finally, we show that the introduction of a minimum wage boosts demand and avoids the failure of the system.

2   The model

The model presented follows the principles of the agent-based computational approach:

> An agent-based model is a computerized simulation of a number of decision-makers (agents) and institutions, which interact through prescribed rules. (. . .) Such models do not rely on the assumption that the economy will move towards a predetermined equilibrium state, as other models do. Instead, at any given time, each agent acts according to its current situation, the state of the world around it and the rules governing its behavior. (Farmer and al. 2009b)

Seppecher (2009) gives a complete description of the model. However, in this first version, the unique bank was perfectly accommodating. We abandon this hypothesis and instead assume that bankrupt firms do default. This assumption opens the possibility of a bankruptcy of the banking system and thereby a systemic crisis.

2.1   General characteristics

The model is formed by two coupled systems: the first one representing the real sphere, the second the monetary sphere. The rules of functioning of these two systems impose upon the agents. The model is implemented in an object-oriented language (Java) where the encapsulation of the real and monetary data within objects ensures:

- the respect of the physical constraints: rules of production, transfer and destruction of the goods,

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- the respect of the monetary constraints: rules of creation, transfer and destruction of the money.

Figure 1 proposes a representation of the real and monetary interactions projected on two parallel plans.
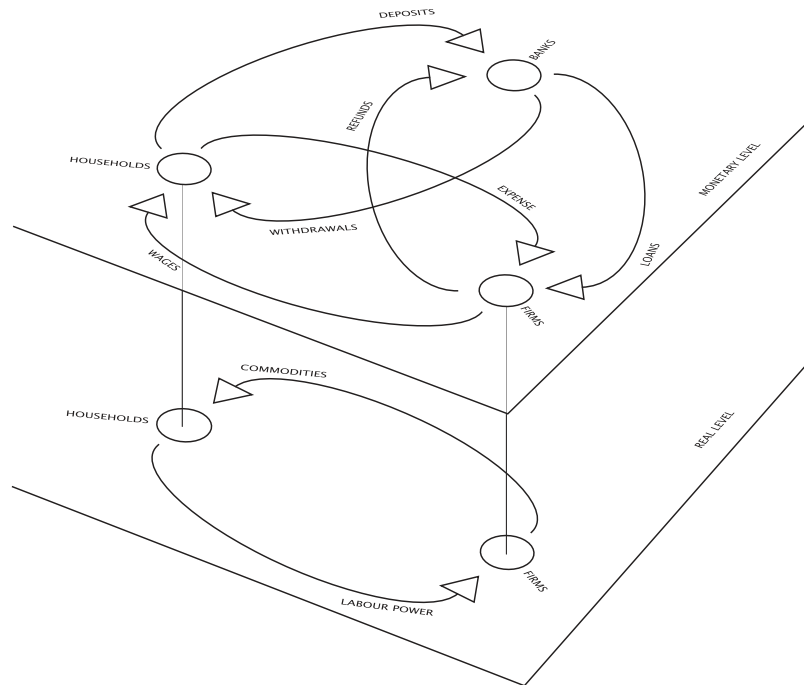

Figure 1: The interactions of the agents at the real and monetary levels

The model contains three types of agents: firms (one hundred), households (one thousand) and banking sector (one single representative bank).

2.2 The bank

In its role of payment agent, the bank has no autonomy. It simply executes the payment orders of the accounts holders, as long as accounts exhibit positive balance.

In its role in production financing, the bank is accommodating: it accepts all the applications for credit of firms.

When a firm is unable to pay off a credit in due terms, the bank grants it automatically a new loan noted *doubtful*. The amount of this new loan is enough to allow the firm to pay off at once the initial loan. On the other hand, when one firm is unable to pay off a doubtful debt when due, the firm goes bankrupt and disappears. The bank then has to absorb the defaulted debt.

For that purpose, the bank has a cash reserve (the bank's capital) from which it draws to erase the debt of the failing firm. The bank uses then its resources (the payment of the interest by firms) to reconstitute its capital until the required level. The surplus of its resources is paid to its shareholders as dividends.

However, sometimes, the bank's capital may be insufficient to face the bankruptcy of a debtor. The unique bank goes bankrupt itself and the simulation breaks off.

2.3 Firms

At the beginning of each period, every firm determines its objective of production. Firms do not observe exactly the condition of the goods market but instead estimates it based on the level of their own stock of unsold goods. When its stocks are large, a firm lowers its levels of production and employment.

The firm then updates the wage offered on the labor market. There also, the reaction of the firm depends on its own estimate of the labor market situation. If during several consecutive periods the firm has experienced difficulties in recruiting employees, then it increases its starting wage.

The firm can then calculate its payroll and determine its need for external financing. The desired loan is automatically tuned by the bank. The firm posts its offer on the labor market. The households which answer this offer are paid and employed by the firm.

Once the phase of production is finished, the firm determines its price. The new price depends on the level of inventories after production. If the firm judges that the level of inventories is too high, it lowers the price, otherwise it increases the price. The firm posts then its offer on the goods market and satisfies the demand of the households at that price.

The firm now must pay off the fallen debts. As we have already explained, if the firm has not enough money to pay off its doubtful debts, it immediately goes bankrupt and disappears. Its debt is erased, absorbed by the bank.

Each period, the profits of the firm are formed by its revenues from sales minus the costs of production (wages and interests on loans). When profits are positive, the firm distributes a fraction to households through dividends and keeps the rest to build up internal-financing for future production.

2.4 Households

Like firms, households have only a limited knowledge of the labor market. Every unemployed household makes a search: it consults the offers of a limited number of employers chosen at random among all the offers posted on the labor market. The household holds the higher wage offer among the consulted offers. If the wage offer is higher than its reservation wage, the household accepts the job and it is hired at once by the firm. Otherwise, it remains unemployed for this period. The level of the reservation wage depends on the number of periods

spent in unemployment. After a certain duration, the unemployed household resigns to lower its reservation wage.

Once the labor market closed, the firms pay the employed households. In exchange, these expend their labor power in the implementation of the process of production. The household income is the sum of the wage of the period and the possible dividends paid by firms and bank. The households save a part of their income, and spend the other one on the goods market.

As on the labor market, the households have only a limited knowledge of the goods market: each consults only a number limited of bids, and chooses among them the most interesting.

3 Baseline scenario

3.1 Emergence of a macroeconomic stability

We make a large number of simulations by varying one after the other each of the main parameters of the model. We find that the model is able to reproduce itself from one period to another, in a wide space of parameters, with strong regularities of behavior. Then we test these regularities by simulating an exogenous shock at given date by the rough variation of one of the parameters of the model. Figures 2a and 2b show the consequences of two of these shocks on the distribution of income between wages and profits.
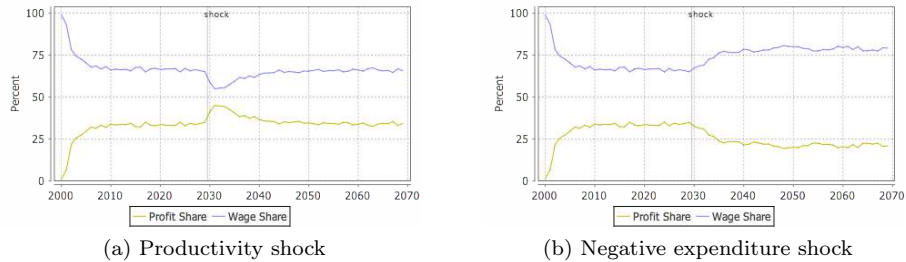

(a) Productivity shock (b) Negative expenditure shock

Figure 2: Effects of an exogenous shock on the income distribution

At first, the macroeconomic stability of the model is deeply affected by the shock of productivity. This shock entails an increase of the profitability of firms, and thus an increase of the profits. But on the long term the effects of this shock ease and disappear, the distribution of incomes finding its previous level.

In another scenario, to simulate the effects of a negative expenditure shock, we double the households saving propensity. Again, the shock entails in the short term a deep destabilization of the model. On the long term, the distribution of incomes is stabilised again, this time with a lower level for the share of the profits. We can show that a new inverse shock, returning the households saving

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propensity at its previous level, would allow to restore the previous levels of the distribution.

Beyond these two examples, all the simulations we made show that there is a wide range of values in the space of the parameters of the model for which we observe a long-term stability of the income distribution. The macroeconomic equilibrium of the model seems strongly connected to this stability.

Nothing in the behavior assigned to firms allowed to anticipate the stability of the distribution of incomes between wages and profits. We saw that firms set the prices and the wages in a strictly independent way. In particular, every firm ignores its costs and can easily sell its production below its production cost (the latter being essentially formed by the payment of wages). Nevertheless, we observe that the average price on the goods market settles above the production cost at a level stabilising the average margin of firms and, thus, stabilising the share of the profits in the total income.

The long-term stability of the income distribution between wages and profits, main appearance of the macroeconomic equilibrium of the model, is thus an emergent property of the model, testifying of the existence of a macroscopic coordination between the price formation on the goods market and the wages formation on the labor market.

This emergent property of the model illustrates the observation of Keynes, according to whom the stability of the income distribution constitutes a 'well-known statistical phenomenon':

> The stability of the proportion of the national dividend accruing to labour (...) is one of the most surprising, yet best-established, facts in the whole range of economic statistics, both for Great Britain and for the United States. (. . .) the result remains a bit of a miracle. (Keynes 1939)

3.2 Rigidity of wages

In the baseline scenario, the resistance of the unemployed households to a decrease of wages is fixed to 8 months on average (between 4 and 12 months). For these first months of unemployment, the reservation wage of each household is equal to the last wage earned by the household when it was employed. After this laps, the household which did not find a job lowers its reservation wage of 10 percent (figure 3a).

However, after the first five years of the simulation, the average duration of unemployment becomes established in approximately two and a half months (figure 3b). Most of the unemployed households thus find a job before lowering their reservation wage. In these circumstances, wages seem very sticky downward. This rigidity appears as responsible for the simultaneous presence of vacancies and unemployed households (figure 3c). The orientation of the curve of Beveridge shows that the number of vacancies and the number of unemployed households varies in the same direction (figure 3d).

The households staying without a job in the baseline scenario appear to be
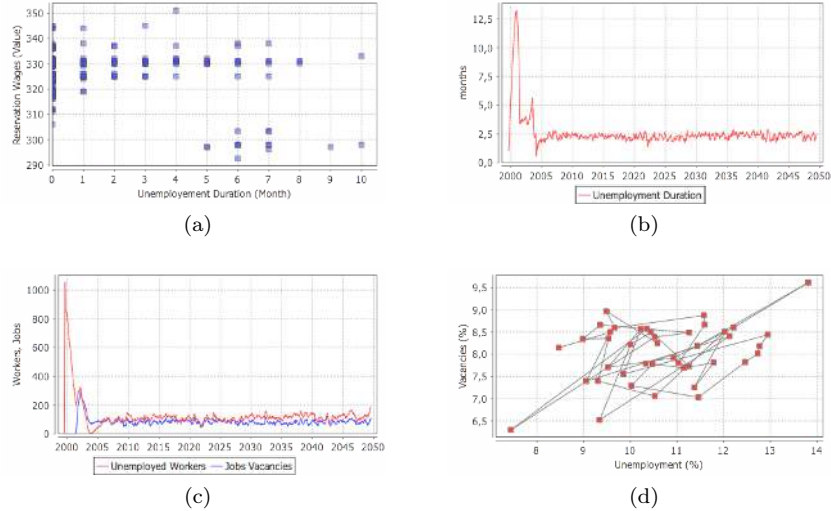
Figure 3: Rigidity of wages in the baseline scenario

responsible for their condition, because we notice simultaneously vacant jobs. The unemployment so observed is usually considered as 'voluntary unemployment'.

4 Experiments on the labor market

In Seppecher (2010), we showed the essential role played by the banking system in the emergence of the macroeconomic stability of the model. Here, we wonder if the rigidity of the labor market plays a role in this emergence.

By a first experiment, we test the stability of the model by increasing the flexibility of the nominal wages.

By a second experiment, on the contrary we strengthen the downward rigidity in nominal wages by introducing a minimum wage.

4.1 Flexibility of wages

We modify the reference scenario by reducing, from 2030, the resistance of the households to a drop of wages. From this date the households agree to lower their reservation wage after 3 months of unemployment on average (between 2 and 4 months).

At first sight, the results on the labor market are in accordance with the expected effects. The unemployed households lower more quickly their reservation wage (figure 4a). The average duration of unemployment is reduced (figure 4b). The curves of the number of vacancies and the unemployment figures are
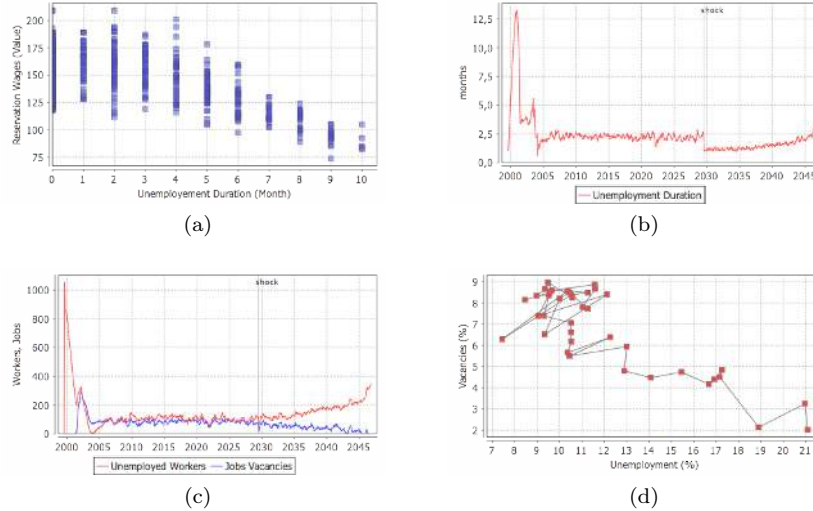
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Figure 4: Flexibility of wages: effects on the labor market

disconnected (figure 4c). The curve of Beveridge takes a perpendicular direction to that observed in the baseline scenario (figure 4d).

However, the weakening of wages (figure 5a) affects the demand. The consumption passes under the production (figure 5b) and the inventory stocks of firms increase. Companies react by lowering their prices (figure 5c) but also by reducing the level of the production, what is translated into an increase of the unemployment (figure 5d).

This feedback on the labor market, by increasing the number of unemployed households, increases the competition between these, and leads them to accept incessantly new reduction in wages. The deflation process, set off by the first drops of wages, grows and strengthens itself.

The curse of the Phillips curve illustrates the sinking of the economy in the depression (figure 5e). The drop of nominal wages, faster than the drop of prices, drives to a decline of the real wages (figure 5f). The income distribution is destabilised in favor of the share of the profits (figure 5g). Companies have more and more difficulties to pay off the bank when due. Bad debts increase, bankruptcies grow, affecting the capital of the bank (figure 5h), until leading this one to failure.

Because the model is endowed with an unique bank representative of the whole banking system, the bankruptcy of this bank translates the impossibility to respect the reflux constraint of the money, imposed by the credit nature of the money. The crisis is systemic and the simulation breaks off.
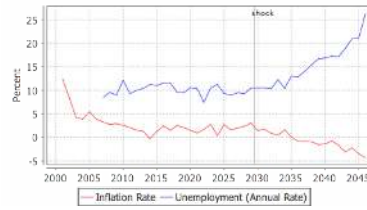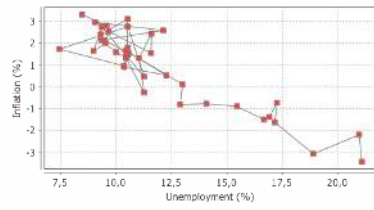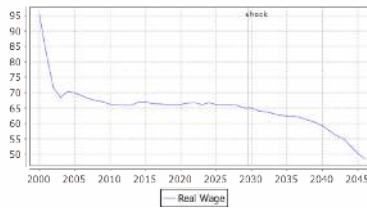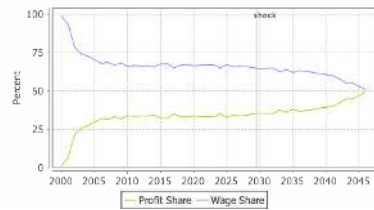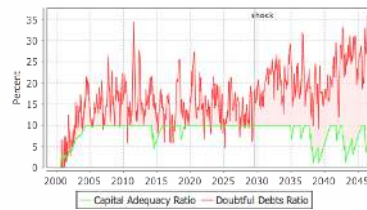
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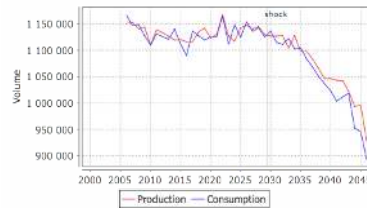
(b)

(c)

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(f)

(g)

(h)

Figure 5: Wages flexibility: effects on demand and activity

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4.2   Institution of a minimum wage

We modify again the scenario. We keep the modification of the flexibility of wages in 2030 but we introduce in 2045 a minimum wage.

The institution of the minimum wage interrupts the fall of wages (figure 6a). However, as at first the prices pursue their decline (figure 6b), the employed households see their real wage increasing (figure 6c). The consumption exceeds the production (figure 6d) and the inventory stocks of firms fall. This demand recovery leads firms to interrupt the drop of the prices (figure 6e) and to increase the production.

The unemployment decreases (figure 6f) and the wage bill increases, feeding again the demand. The economy goes up again along the Phillips curve (figure 6g) and stabilises at levels of activity higher than those observed in the reference scenario. The distribution of incomes between wages and profits returns to levels close to those of the baseline scenario (figure 6h).

5   Conclusion

According to Keynes,

> Economics is a science of thinking in terms of models joined to the
> art of choosing models which are relevant to the contemporary world.
> (Keynes 1938)

The agent-based computational methods allow to model complex systems populated with a large number of autonomous and heterogeneous agents. Using this approach, we built a computational model of a dynamic and complex economy in which the interactions between the agents are real and monetary.

We notice the emergence of a macroeconomic stability — characterized by the long-term stability of the distribution of the total income between wages and profits. In its basic version, this model contains a very rigid labor market. The unemployed households strongly resist against the fall in the nominal wages that firms try to impose. This resistance generates the simultaneous persistency of a significant number of unemployed households and vacancies.

We have then modified the resistance to downward nominal wage flexibility by forcing unemployed households to accept lower wages more easily. While households are more flexible to the demands of employers, we observed no sustained reduction in level of unemployment. In contrast, downward wage adjustments lead to a weakening demand. This weakening of demand led firms to lower commodity prices but also the level of production, with consequent increases in unemployment. It sets up a self-feeding process of deflation that only the bankruptcy of the banking system will stop.

This scenario illustrates and confirms the reasoning of Keynes, which leads him to assert that a fall of the nominal wages cannot assure the full employment, and could even destabilize prices and the whole economic system.
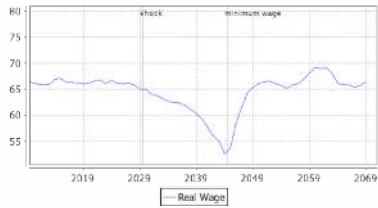
The following scenario, with institution of a minimum wage, confirms the importance of wage rigidity for the emergence of the macroeconomic stability
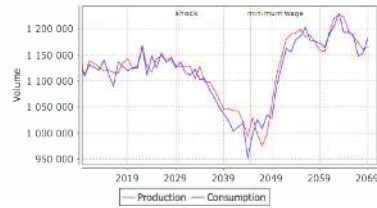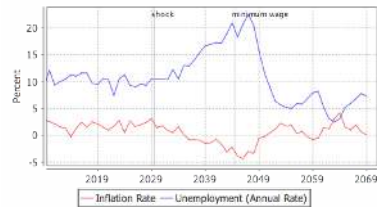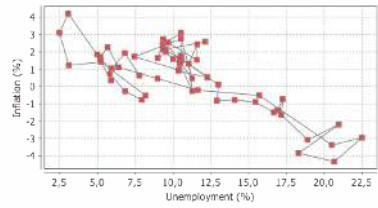
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Figure 6: Institution of a minimum wage

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noticed in the baseline scenario. According to Keynes, it is the monetary character of the considered economy that explains the importance of this rigidity for the equilibrium of the system:

> In fact we must have some factor, the value of which in terms of money is, if not fixed, at least sticky, to give us any stability of values in a monetary system. (Keynes 1936)

The model which we used remains still very simple with respect to the requirements expressed by Keynes in the General Theory. Nevertheless, no theoretical obstacle seems to rule out extensions to the elements of the real world which have been disregarded in this first version.

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