Network Externalities and Comparative Advantage

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Abstract

In this article I examine how the network externalities of communications activities and trading opportunities interact to determine the structure of comparative advantage. These interactions are examined by constructing a two-country, three-sector model of trade involving a country-specific communications network sector. The role of the connectivity of network providers, which allows users of a network to communicate with users of another network, is also explored. (JEL Classification: D43, F12, L13)

1 Introduction

The rapidly growing connectivity of individuals and organizations achieved through improved communications networks (e.g., the Internet, mobile telephone networks, and satellite communications systems) has allowed a consequent increase in the flow of business transactions. These networks are often characterized by the existence of strong *network externalities*: the more people who use them, the more useful they are to any individual user. Accordingly, sophisticated and well-connected country-specific networks have become recognized as the 'competitive weapons' with which battles for comparative advantage are won. In his recent bestselling book, *The World Is Flat*, Thomas Friedman argues as follows:

> ... information technologies are important not only because they are big global businesses in and of themselves, but also because they are critical to advancing productivity and innovation.... The more you connect an educated population to the flat world platform in an easy and affordable way, the more things they can automate, and therefore the more time and energy they have to innovate.... (Friedman, 2006, p. 350)

Friedman also highlights the importance of producers in knowledge-based, high-tech industries, such as the consulting, financial services, software and marketing industries.

The seminal contribution on the role of network externalities is by Katz and Shapiro (1985), who analyzed oligopolistic competition between providers of network services.[1] However, as their model is based on a closed market for a consumption good, the role of network externalities as a determinant of trade patterns is downplayed in the analysis. Since such effects are often observed in the world economy, it seems important to explore the relationship between network externalities and trading opportunities in the open economy setting.

As its primary contribution, this study examines how the network externalities of communications activities and trading opportunities interact to determine the trade patterns between countries. I also emphasize an important concept related to network externalities –*interconnectivity*–which allows users of a network to communicate with users of other networks.[2]

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[1] See Katz and Shapiro (1994) and Roson (2002) for surveys of the relevant literature.

[2] Cremer et al. (2000) explores the role of interconnectivity between Internet Service Providers (ISPs) in the closed-economy setting. Yano and Dei (2006) explores the impact of the introduction of a new product which is accompanied by network externalities. Kikuchi

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For these purposes I construct a two-country, three-sector model of trade with country-specific communications networks. It will be shown that the good that requires network services is exported by the country with interconnected networks. The main result of the current study, which captures the importance of interconnectivity of networks as a determinant of comparative advantage, has not appeared in the existing literature on trade theory under increasing returns, which only emphasizes the size of countries.

The structure of this paper is as follows: In the next section I present the basic model. The nature of the trading equilibrium is considered in Section 3. Section 4 explores several directions in which the model could be extended and Section 5 offers concluding remarks.

2 The Model

Consider a world economy consisting of two countries, Home and Foreign. There are two goods: a primary commodity which is produced only by labor and a knowledge-based, high-tech product which is produced with both

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(2003) explores the role of interconnectivity using a monopolistically competitive trade model. However, that article offers little insight into the role of network externalities as a determinant of comparative advantage, which is the main focus of this note.

human capital and communications services. Communications services are assumed to be provided by country-specific *network service providers*. The n identical providers in each country are Cournot competitors. Providers are indexed by label i ($i = 1, ..., n$). Let x_i denote the size of the i-th provider (i.e., the number of subscribers), y_i denote the size of the network with which the i-th provider is associated, and z denote ($z = \sum_{i=1}^{n} x_i$) the total number of network users. For example, when provider 1 and provider 2 are interconnected, $y_1 = y_2 = x_1 + x_2$.

Let the high-tech product be the numeraire and p indicate the relative price of the primary good. The primary good is produced under constant returns technology; units are chosen such that its unit input coefficient is unity.

Each country is populated by a continuum of workers with population L. Each worker is endowed with one unit of labor and some level of human capital for the production of the high-tech product, which is measured by index r. The values of r are uniformly distributed over the interval $[0, \ L]$. Each worker's productivity is also affected by the level of network externalities, vy_i^e, where v ($v \leq 1$) is a valuation parameter and y_i^e is the worker's expectation of the size of the (i-th) network. The v term captures gains

through increased information flow between individuals: if more workers join the network, each worker can collect information more efficiently. It is simply assumed that a type-r worker can produce $r + vy_i^e$ units of the high-tech product.

Workers have the choice of either supplying labor for the production of the primary good or becoming suppliers of the high-tech product, and workers will become the latter only if they connect to a communications network. To connect to the i-th provider's network, each worker must pay a connection fee, f_i, in exchange for unlimited access up to the maximum throughput of their particular connection. In other words, f_i can be interpreted as the price of the i-th provider's services. A type-r worker chooses to connect to the network for which

$$r + vy_i^e - (f_i + p) \tag{1}$$

is the largest. This can be interpreted as follows: If $r + vy_i^e - f_i \geq p$ holds for a particular worker, that worker pays the connection fee and starts to produce the high-tech product. However, if $r + vy_i^e - f_i < p$ holds, that worker chooses not to connect to the network and produces the primary good instead. As p rises, more workers choose not to connect to the network. Thus, one can interpret $(f_i + p)$ as a connection fee including the outside option.

In equilibrium, providers i and j will both have a positive number of subscribers only if

$$(f_i + p) - vy_i^e = (f_j + p) - vy_j^e, \tag{2}$$

where $(f_i + p) - vy_i^e$ is the connection cost adjusted for network size.[3] Let Φ denote the common value of this cost. For a given value of Φ, only those workers for whom $r > \Phi$ become producers of the network good. Given the uniform distribution of r, there are $L - \Phi$ workers who choose to connect to the networks. Thus, if the total number of network users is z, $z = L - \Phi$ holds. Then, by substituting $\Phi = (f_i + p) - vy_i^e$ into this, we obtain the condition for the connection fee:

$$f_i = L - p + vy_i^e - z. \tag{3}$$

To simplify the analysis, I assume that the production cost for each provider is equal to zero. Thus, the i-th provider's profits are

$$\pi_i = x_i f_i = x_i(L - p + vy_i^e - z). \tag{4}$$

Each provider chooses its optimal number of subscribers by differentiating eq. (4) with respect to x_i.

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[3] (2) implies that in equilibrium all the existing networks necessarily provide the same 'surplus,' which is defined as (1).

Before turning to providers' behavior, let us consider the equilibrium supply level of the high-tech product. By Equations (1) and (3), a type-r worker can produce $r + z + f + p - L$ units of product. Furthermore, only those workers for whom r is greater than $L - z$ join the network, while the others choose to produce the primary good. Integrating all workers who do connect to the networks, we can obtain the total output of the high-tech product:

$$S(z) = \int_{L-z}^{L} (\rho + z + f + p - L)d\rho = (z^2/2) + (f + p)z. \qquad (5)$$

We can interpret this as the supply function of the high-tech product. This function is represented by OS in Figure 1(b). As the total number of network users becomes larger, the average productivity of each high-tech product supplier rises: $[S(z)/z]' > 0$. This is shown as lines OA and OA' in Figure 1(b). Each country thus has a supply function that exhibits increasing returns to the size of the networks.

There are two sources of these gains: (1) as more workers join the networks and the total number of subscribers increases, each infra-marginal worker can attain higher productivity through intensified network externalities; and (2) through these network externalities, each service provider chooses to set a lower connection fee, which further attracts more workers.

More noteworthy is that, in terms of income inequality between sectors, as the size of the networks becomes larger, income inequality between sectors increases.[4]

Depending on the interconnectivity between providers, several cases can emerge as the production equilibrium. The following subsections discuss two special cases: fully interconnected networks and unconnected networks.

2.1 The Case of Interconnected Networks

Let us assume that n providers are fully interconnected.[5]   A user who connects to one network can communicate with users of other networks. Interconnectivity expands the size of each network to the total membership of all providers. This raises the productivity gains enjoyed by a worker who subscribes to only one provider's network because network externalities depend on the total size of the network (i.e., $z = x_1 + ... + x_n$). Equation (4) becomes

$$\pi_i = x_i(L - p + vz^e - z).$$

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[4] Note that productivity in the primary good remains constant.

[5] As space is limited, I concentrate on the nature of the equilibrium and pay scant attention to the factors that determine interconnectivity. The case of endogenous formation of interconnected networks will be discussed in Section 4.

Maximizing this with respect to x_i, we obtain

$$x_i = L - p + vz^e - z.$$

Imposing the requirement that in equilibrium workers' expectations are fulfilled (Fulfilled Expectation Equilibrium), $z^e = z = nx$ holds. Then we obtain the equilibrium number of subscriber for each provider:

$$x = (L - p)/(n + 1 - nv). \tag{6}$$

By summing Equation (6) over all providers, we obtain the total network size as a function of the relative price of the high-tech product $(1/p)$.

$$z^I(1/p) = [n(L - p)]/(n + 1 - nv), \;\; z^{I'} > 0, \tag{7}$$

where superscript I denotes the fulfilled expectations equilibrium value when the networks are fully *interconnected*. The equilibrium is depicted in Figure 1(a). The horizontal axis shows the total size of the network, z, while the vertical axis shows the values of $L - p + vz$ and $[(n + 1)z]/n$. Equilibrium is obtained at an intersection of two curves: line ON represents $[(n + 1)z]/n$ while the other curve represents $L - p + vz$. As p becomes smaller, the curve will shift upward, which results in a larger total size of the network.

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2.2 The Case of Unconnected Networks

Next, let us consider the case in which n providers are not connected to each other. Subscribers on one network cannot communicate with those on the other networks. In this case, $y_i = x_i$ holds. If there exists a symmetric equilibrium, $x = z/n$ holds. Thus, instead of (6), we obtain,

$$z^U(1/p) = [n(L-p)]/[n+1-v], \qquad (8)$$

with superscript U denoting the equilibrium value of the *unconnected* networks. This case is represented by the dotted curve in Figure 1(a). Since network externalities are smaller than in the case of interconnection, the equilibrium total size of the network, z^U, also becomes smaller than z^I. With these figures we obtain the supply curves of the high-tech product (Figure 2). The supply curve of the country with interconnected networks is located to the right of the country with unconnectd networks.[6]

3   The Impact of Trade Integration

Suppose that the only difference between two countries is the interconnectivity of the country-specific communications networks. Without loss of gen-

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[6] Note also that, since productivity rises as the relative price of the high-tech product rises, the supply curves have concave shapes.

erality, Home is assumed to have interconnected networks while Foreign has unconnected networks. Also, let each country have the same demand function for the high-tech product, $D(1/p)$ $(D' < 0)$ which is shown as a downward sloping curve in Figure 2.[7] Note that $z^I > z^U$ $(S > S^*)$ holds.[8] Let us define the export supply functions of the high-tech product:

$$E(1/p) \equiv S[z^I(1/p)] - D(1/p), \tag{9}$$

$$E^*(1/p) \equiv S^*[z^U(1/p)] - D(1/p). \tag{10}$$

Autarky equilibrium requires that $E = E^* = 0$. Thus, from (9) and (10), Home has the lower autarky price for the high-tech product (i.e., $(1/p) < (1/p^*)$).

Now suppose that Home and Foreign open their goods markets and have a trading relationship. The opening of trade provides an opportunity for entry into Home's high-tech product sector because, with the expanded network size, the average productivity of Home workers is much higher than that of Foreign workers. Furthermore, as trade opens and $(1/p)$ rises, more Home workers choose to subscribe to the networks. From their viewpoint,

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[7] Note that we assume away any income effect.

[8] In what follows, $*$ denotes variables for Foreign.

producing the primary good becomes less attractive.[9] At the same time, as $(1/p^*)$ falls, producing the high-tech product becomes less attractive in Foreign. Thus, the scale of Home (interconnected) networks will expand while Foreign (unconnected) networks will contract. The differences in the network sizes will be reinforced by this entry-exit process. In Home, additional entry of new workers enhances exports of the high-tech product: $E'(1/p) > 0$. Through these mechanisms, the circular relationship between network expansion and trade creation continues. That is, there will be a *cumulative process* in which the opportunity for trade (i.e., an increase in price) brings about the opportunity for larger networks, and the increased sizes of the networks promote (through intensified network externalities) exports. This process will continue until the price differential between countries disappears. From (9) and (10), the trading equilibrium price $(1/p^T)$ is determined by the following condition:

$$E(1/p^T) - E^*(1/p^T) = 0. \tag{11}$$

Proposition 1: *A comparative advantage in the high-tech product is held by a country with interconnected networks. If the two countries commence free trade from autarky, the country with interconnected networks incompletely*

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[9] Note that $r + vz - f = p$ holds for the marginal worker.

specializes in the high-tech product and the country with unconnected networks incompletely specializes in the primary good.

Note the impact of trade on income inequality between sectors *within* each country. Since productivity in the primary-good sector remains constant (i.e., one unit of labor produces one unit of the primary good), we only have to concentrate on the productivity in the high-tech product sector. As I have shown in the previous section, the size of the networks positively affects productivity. Since $(1/p) < (1/p^T) < (1/p^*)$ holds, the size of the Home network expands $(z(1/p^T) > z(1/p))$ while the Foreign one contracts $(z^*(1/p^T) < z^*(1/p*))$. This change raises the Home high-tech sector's productivity, so we can say that Home's income inequality between sectors becomes greater with the opening of trade. Similarly, we can say that Foreign's income inequality between sectors becomes smaller as the result of trade.

Proposition 2: *International trade increases inequality in the country that exports the high-tech product and reduces inequality in the country that exports the primary good.*

4 Discussion

In this section I describe two directions in which the model could be extended. First, rather than trade between a country with fully interconnected networks and a country with unconnected networks, consider trade between two countries in which the networks are partially interconnected. Analyses in previous subsections reveal that the total size of the network under autarky determines comparative advantage. For illustrative purposes, assume that Foreign networks remain unconnected. Even if only Provider 1 and Provider 2 in Home are fully interconnected (i.e., $y_1 = y_2 = x_1 + x_2$) and the remaining $n - 2$ providers are unconnected, the size of Home's network is larger than that of Foreign's due to intensified network externalities between Provider 1 and Provider 2. As in the previous section, Home becomes a net exporter of the high-tech product. Since there are various types of partial interconnection, formal modeling of trade under partially connected networks is beyond the scope of this note. Thus, there is room for further investigation.

Secondly, let us consider the endogenous formation of interconnected networks.[10] In analyzing this I will look at each provider's change in profits,

$$\Delta \pi \equiv \pi^I - \pi^U,$$

[10] I would like to thank an anonymous referee for suggesting this.

where π^I (π^U) represents each provider's profits in the case of interconnected (unconnected) networks. Also, I assume that there is a fixed cost for interconnection, f, which each provider must pay before interconnection. Substituting equilibrium output levels into the profit function (4), we can calculate each provider's equilibrium profits as $\pi^I = (L-p)^2/(n+1-nv)^2$ and $\pi^U = (L-p)^2/(n+1-v)^2$. Thus, the change in profits becomes:

$$\Delta\pi = (L-p)^2[(n+1-nv)^{-2} - (n+1-v)^{-2}] > 0.$$

Note that both the population size (L) and the magnitude of network externalities (v) positively affect this change, while the number of providers (n) negatively affect it. Incentives for interconnection depend on the relationship between $\Delta\pi$ and f. If $\Delta\pi > f$ holds, each provider chooses to connect and interconnected networks emerge. If $\Delta\pi < f$ holds, however, networks remain unconnected. This result has important policy implications. Through subsidization of the fixed cost of interconnection, one country may acquire a comparative advantage in high-tech products.[11] Further research should focus on these policy implications.

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[11] Furthermore, a natural extension would consider international policies to coordinate the subsidization of interconnected networks. The benefit of such policies are debatable.

5 Concluding Remarks

This study highlights the role of network externalities as a driving force behind trade in knowledge-based, high-tech products. It should be emphasized that differences in connectivity among country-specific communications networks determine the comparative advantages of countries. When two countries are endowed with equal amounts of labor, the country with connected networks can attain higher productivity with its superior information-handling capabilities. This outcome differs from results obtained from trade models with increasing returns and imperfect competition. In those models, a country with either a larger factor endowment or a larger domestic market acquires a comparative advantage in the good that is produced under increasing returns to scale technology.[12] The present model suggests, however, that even a smaller country can acquire a comparative advantage in a high-tech product via the utilization of interconnected networks. What really matters is interconnectivity rather than country size. More noteworthy is that there is a circular process between network expansion and trade creation which further affects income inequality within each country.

Although these results are derived under the assumption that communica-

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[12] See, for example, Helpman and Krugman (1985, Chs. 3 and 10).

tions networks are purely country-specific, it appears that something similar to this will occur in more general settings. The present analysis must be regarded as very tentative. Hopefully, it provides a useful paradigm for the consideration of how communications infrastructure works as a driving force for international trade.

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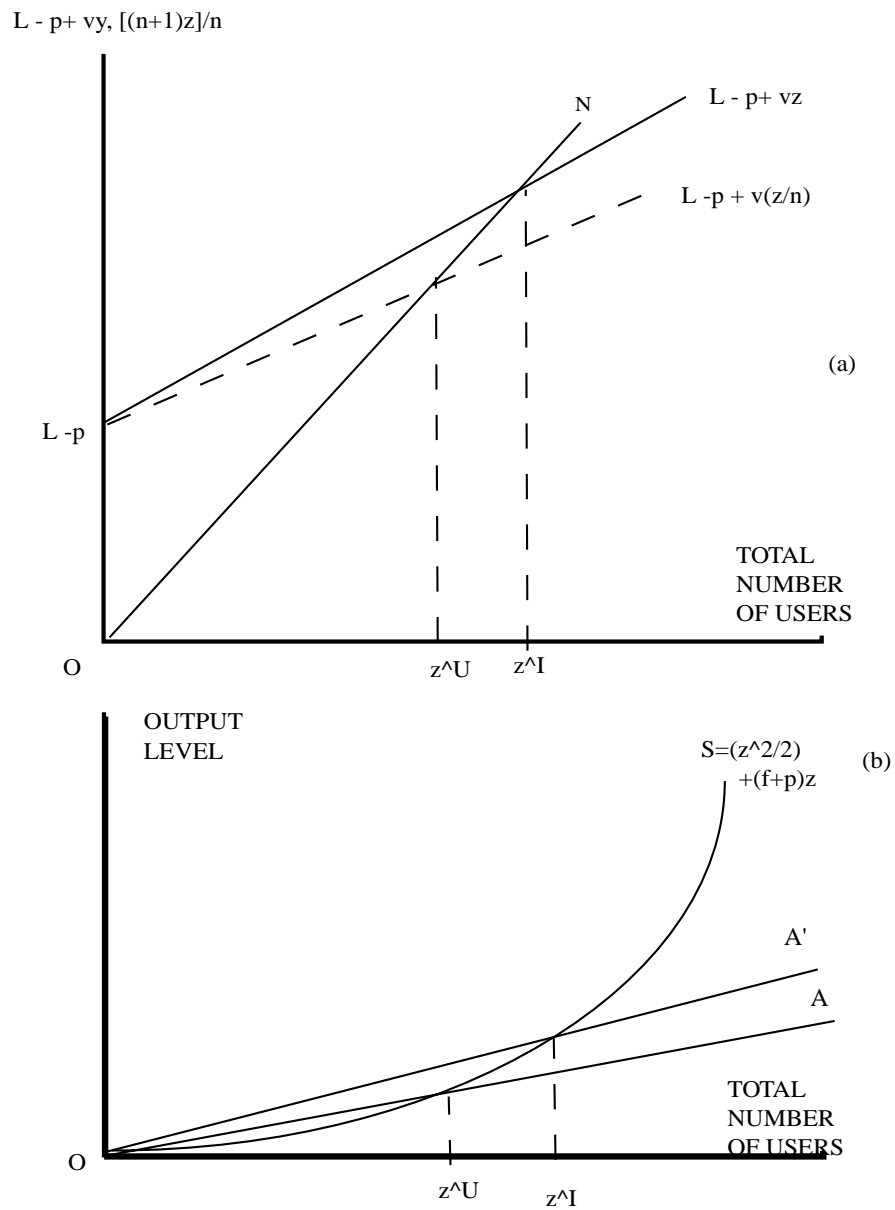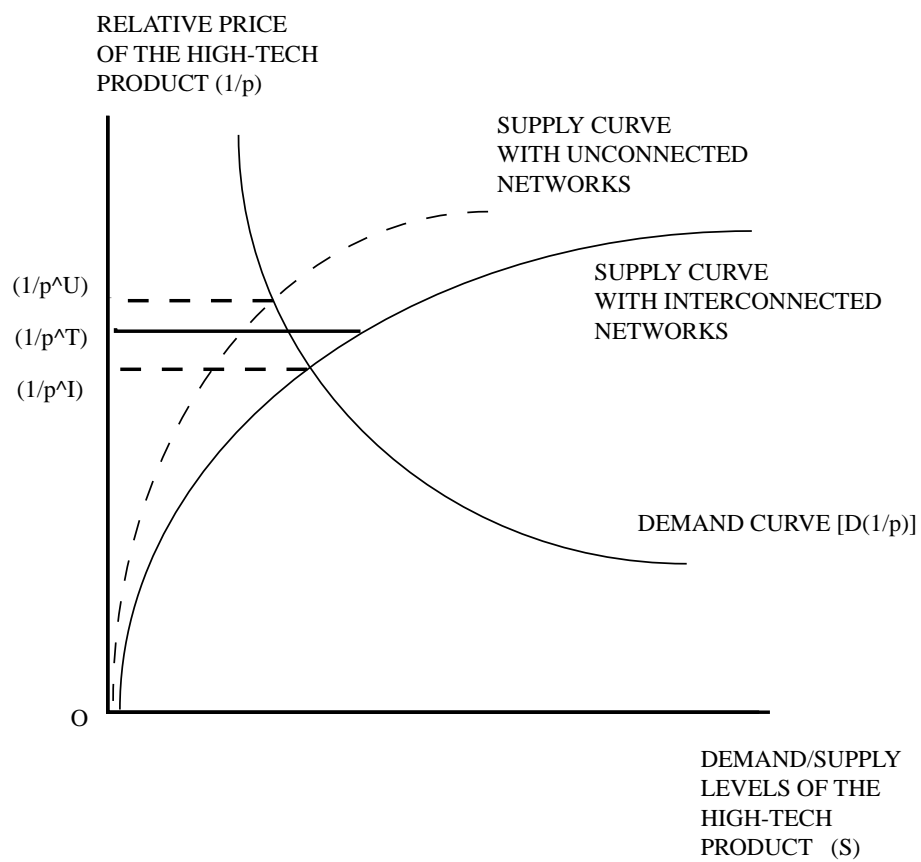
L - p+ vy, [(n+1)z]/n

N

L - p+ vz

L -p + v(z/n)

(a)

L -p

TOTAL
NUMBER
OF USERS

O   z^U   z^I

OUTPUT
LEVEL

S=(z^2/2)
+(f+p)z

(b)

A'

A

TOTAL
NUMBER
OF USERS

O

z^U   z^I

FIGURE 1

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RELATIVE PRICE
OF THE HIGH-TECH
PRODUCT (1/p)

SUPPLY CURVE
WITH UNCONNECTED
NETWORKS

(1/p^U)

(1/p^T)

(1/p^I)

SUPPLY CURVE
WITH INTERCONNECTED
NETWORKS

DEMAND CURVE [D(1/p)]

O

DEMAND/SUPPLY
LEVELS OF THE
HIGH-TECH
PRODUCT   (S)

FIGURE 2

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