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PUBLIC OWNER WITH BUSINESS DELIVERY MODE IN CHINA: CASE STUDY OF THE SHANGHAI PUBLIC BUS SYSTEM

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ABSTRACT: *Since 2008, some of China's municipal governments have reversed the privatization of market-led reform in the bus transport field. But this reversal is not a return to the direct public monopoly delivery model of the past. Instead the new structure is a hybrid of public control with business delivery. This mixed model attempts to balance government, market and social groups. This mode is a contracting network where government plays a lead role to organize the stakeholders to achieve common goals. This paper uses the Shanghai municipality bus service as a case to illustrate this new mode. It argues that the contract between government and operators and the participation of social groups helps balance the control of the government. This mixed network mode of management reduces information asymmetries and promotes shared goals to ensure a higher quality, more responsive service. While not a mixed firm in the sense found in Europe, this mixed public-public contacting network in China offers insights into the core challenges mixed firms have emerged to address.*

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Propriétaire public avec fourniture commerciale en Chine: Une étude de cas de la compagnie de bus publics de Shanghai

Depuis 2008, quelques autorités municipales en Chine ont inversé la réforme de marché tendant à la privatisation dans le secteur du transport par bus. Mais ce retournement n'est pas un retour au modèle du monopole public de fourniture du passé. Il s'agit d'une nouvelle structure hybride de contrôle public avec fourniture commerciale. Ce modèle mixte vise à équilibrer Etat, marché et groupes sociaux. Ce système est un arrangement contractuel où l'Etat joue un rôle de leader pour amener les parties prenantes à atteindre des objectifs communs. Cet article se base sur le transport municipal de bus à Shanghai pour illustrer ce nouveau mode d'organisation. Il prouve que le contrat entre Etat et opérateurs avec la participation de groupes sociaux contribue à équilibrer le contrôle de l'Etat. Ce mode de gestion mixte en réseau réduit les asymétries d'information et favorise des objectifs communs (partagés) pour garantir une qualité supérieure et un service répondant mieux aux besoins. Quoique ne correspondant pas à l'entreprise mixte au sens européen, cet arrangement contractuel mixte en réseau de type public-public en Chine offre un aperçu des défis majeurs que les entreprises mixtes sont appelées à relever.

Öffentlicher Eigentümer und Verfahren zur unternehmerischen Leistungserstellung in China: Fallstudie über das Shanghai Public Bus System

Seit 2008 haben einige Stadtverwaltungen in China die marktausgerichtete Reform der Privatisierung im Bereich des Omnibusverkehrs rückgängig gemacht. Doch bedeutet diese Umkehr nicht eine Rückkehr zum früheren Modell der direkten öffentlichen monopolistischen Leistungserbringung. Vielmehr ist die neue Struktur ein Hybrid aus öffentlicher Kontrolle und unternehmerischer Erbringung. Mit diesem Mix-Modell wird versucht, ein Gleichgewicht zwischen öffentlicher Hand, Markt und sozialen Gruppen herzustellen. Das Verfahren besteht darin, ein kontrahierendes Netzwerk zu bilden, bei dem die öffentliche Hand eine führende Rolle dabei spielt, die Stakeholder zur Erreichung gemeinsamer Ziele zu bringen. Der Beitrag bezieht sich auf den städtischen Busverkehr von Shanghai als ein Fall zur Illustration dieses neuen Vorgehens. Es wird festgestellt, dass der Kontrakt zwischen öffentlicher Hand und Betreibern sowie die Beteiligung von sozialen Gruppen hilfreich für das Ausbalancieren der Kontrolle der öffentlichen Hand sind. Dieses Managementverfahren mittels eines gemischt zusammengesetzten Netzwerks reduziert Informationsasymmetrien und bringt die gemeinsamen Ziele der Sicherung höherer Qualität und zufriedenstellender Dienstleistungen voran. Ohne ein gemischtwirtschaftliches Unternehmen im europäischen Sinn zu sein, bietet dieses gemischt öffentlich-öffentlich zusammengesetzte kontrahierende Netzwerk in China Erkenntnisse über die zentralen Herausforderungen, zu deren Bewältigung gemischtwirtschaftliche Unternehmen geschaffen wurden.

Propiedad pública y aprovisionamiento comercial en China

Desde 2008, algunas comunas municipales han invertido en China la reforma del mercado tendente a la privatización en el sector del transporte por autobús. No obstante, este retorno no es un regreso al modelo del monopolio público del servicio en el pasado. Se trata de una nueva estructura híbrida de control público con provisión comercial privada. Este modelo mixto trata de equilibrar el Estado, el mercado y los grupos sociales. El sistema consiste en un compromiso contractual en el que el Estado juega un papel de líder para incitar a las partes implicadas a alcanzar objetivos comunes.

Este artículo se centra en el transporte municipal de autobús en Shanghái para ilustrar este nuevo modelo de organización. En él se prueba que el contrato entre el Estado y los operadores, con la participación de grupos sociales, contribuye a equilibrar el control del Estado. Este modelo de gestión pública en red reduce las asimetrías de información y favorece los objetivos compartidos, para garantizar una calidad superior y un servicio que responda mejor a las necesidades del sector. Aunque no coincide exactamente con el modelo europeo de empresa mixta, este compromiso contractual en red público-privado ofrece en China una primera aproximación a los mayores desafíos que las empresas mixtas están llamadas a desarrollar.

1 Introduction

Local governments are bringing previously contracted public services back in house in a process of reverse privatization around the globe (Hall et al. 2013, Warner and Hefetz 2012, Ramesh et al. 2010). As a result of New Public Management, contracting out or privatization of public services grew over the 1980s and 1990s. However, after about 30 years' development worldwide, many countries have begun to reverse contracting. For example, many European cities are now bringing water contracts back under public control (Hall et al. 2013, Chong et al. 2012).

These reversals represent a reassertion of the public role in the provision of public services in a wide range of public services (from health to transit to water) in countries from Asia to Europe and the USA (Ramesh et al. 2010). New forms of mixed delivery are emerging around the world. While the USA focuses more on a mixed market of public and private providers (Warner and Hefetz 2008), in Europe we see new forms of state owned enterprise emerging (Clifton and Díaz-Fuentes 2010) and the rise of mixed public/private firms (Warner and Bel 2008), multi-utilities (Bognetti and Robotti 2007) and institutionalized public private partnerships (Cruz and Marques 2012).

Reversals also have occurred in China. In China, the market reform of public service is now recognized as a failure (Huang and Ye 2011), and local governments are playing more important roles in public service supply once again. In urban public bus transit, the public sector is once again dominating the service system (Zou 2009). *Shiyan* municipality, located in Hubei Province, regained its operational right for public bus transport service from a private franchise in 2008 after citizens' daily lives were severely negatively influenced by four strikes during the privatization period. In 2009, all the private firms in *Chongqing* and *Shanghai* municipalities withdrew from the public bus transport market. Other municipalities in China, such as *Guangzhou*, *Changsha*, *Zhuhai etc.* also cleared out the private firms and brought their public bus enterprises back under state control.

But the reform of urban public bus transit in China is not the direct government monopoly as before. Instead, the reform emphasizes integration, quality and public welfare. This reassertion of the public role seeks to combine local government accountability with the market mechanism. This requires choosing appropriate public service producers and arrangers based on a better understanding of the advantages and limitations of both the market and the public sector. This paper seeks to articulate what the nature of the new reform is. China follows a unique path of market and public sector reform 'with Chinese characteristics', and this paper seeks to determine if the new reforms in

the urban bus transit sector can be characterized as a Chinese variant of the mixed enterprise hybrids we are seeing emerge elsewhere around the globe.

Reasserting the local government's role actually marks the defeat of a long-standing push for deregulation. It represents a triumph for the government role over more market-led arrangements as Barter (2008) has found in public transit systems around the globe. Borrowing from Blokland et al. (1999), we call this new approach 'public owner with business delivery mode', which is different from the past modes, such as the public owner with public delivery, private owner with private delivery, and mixed owners with mixed delivery. Here, 'public owner' stands for government accountability and public welfare; and 'business delivery', which can improve efficiency, stands for using market rules and mechanisms to deliver the public bus service. By rebalancing the accountability of government, efficiency of market, and consumer voice through social group participation, this new governance mode tries to avoid the problems that occur under any of these modes alone.

The paper is structured as follows. Section 2 provides an overview of urban public bus service governance modes since the establishment of People's Republic of China in 1949. Section 3 describes a case study of the Shanghai public bus system. Section 4 discusses the public owner with business delivery mode, a hybrid form. Section 5 presents the conclusions.

2 Four different governance modes in China

China's public bus service governance has swung like a pendulum between government-oriented and market-oriented modes (Wang *et al*. 2010). China maintained a central planned economy before 1980, when the public bus transport service mode was public owner with public delivery. Local governments established state-owned enterprises to supply all the service. The state-owned enterprises could get government subsidies. But this mode led to low efficiency (Wang *et al*. 2010). From 1980 to 2008, China's governments advocated implementation of market-based reform, which focused on market-driven mechanisms. Private companies and foreign companies were introduced into the public bus transport service supply. In order to balance the interests of multiple participants, governments implemented some regulatory policies to strictly control enterprises' service charges and franchises. The low ticket prices made it difficult for urban bus enterprises to make a profit. Thus, many enterprises applied for price adjustment. But governments often rejected their applications after consideration of citizen concerns. Under these circumstances, bus transport enterprises began to lose money, which led to a lower quality service. After 2008, many municipalities began moving the governance mode back from market-oriented to government-oriented (Wang and Zhu 2013). Today local governments invest more money with more supervision policies than before. The private companies have withdrawn and most of the firms are under public ownership.

Government-oriented and market-oriented are two fundamental modes of public bus transit governance in China (Wang and Zhu 2013). According to New Public Management theory, public bus transport firms selected by the market mechanism may be more efficient and could improve customer satisfaction. Table 1 presents a theoretical

Table 1 – Comparison among different governance modes

Governance mode	Property right	Operation right	Theoretical basis	Goals	Solutions	Problems
Public owner with public delivery (1949-1978)	Government	Government	Bureaucracy	Accountability, Public welfare	Bureaucratic, Planning, Hierarchy, Command and Control	Slow, Inefficient, no contract
Private owner with private delivery (1980s-1990s)	Private enterprise	Operator	Privatization	Efficiency, Reduce public financial burden	Market competition, Performance management	Lack control and accountability
Mixed owners with mixed delivery (1990s-beginning of 21st century)	Government	Operator (during a given period)	Mixed Contract service	Efficiency, Reduce public financial burden	Contract, Trust, Incentive	Imbalance between profit and public interest
Public owner with business delivery (2008-now)	Government	Operator	Contract and Public Control	Efficiency, Public welfare	Supervision, Market, Participation	Lack of sufficient operator independence or consumer voice

classification, which can be used to describe China's public bus transport governance modes. It shows the shifts in theoretical basis, goals, solutions and problems across the different governance modes. An important distinction in the Chinese case is the difference between property rights and operation management rights. Property rights refer to who has the ownership, and operation management rights refer to some level of contractor control – either of public subsidiaries or private market-based firms. Table 1 articulates four fundamentally different categories of bus transport service supply organizations, which we use to describe the history of Chinese public bus transport over the last half century. These four governance modes are public owner with public delivery, private owner with private delivery, mixed owners with mixed delivery and public owner with business delivery mode.

First, under public owner with public delivery mode, government owns the public bus transport firms. As van de Velde (1999) describes, under this traditional public delivery mode, government has the legal monopoly of initiative in the sense that autonomous market entry is legally impossible and all production or market entry is the result of a conscious government decision to produce or request the production of services. Local governments are the providers of public bus transport service, and the direct producers. The aim of this governance mode is to protect the public interest and promote a fair, orderly market by strict control. This is a top-down decision making system. In the planned economy period, China's urban public bus transport services were entirely under public ownership. However, the outcome of this mode was poor quality service and local government had to take entire responsibility for the outcome.

Second, the private owner with private delivery mode involves privatization and deregulation to improve efficiency. Under this scenario local government has limited direct influence over service outcomes. The private enterprise owns the property and operation rights. It is based on the principle of autonomous market entry and results from a market process with more or less regulatory checks at the entrance. The enterprises compete with each other in the field. The success of this mode depends on the capability of government regulation (Wang *et al*. 2010). In the long run, it will be confronted with how to reduce transaction costs (Huang and Ye 2011) and ensure equity and service coordination (Barter 2008). In China, privatization and deregulation didn't work well (Zhou 2009).

Third, mixed owners with mixed delivery is a collaborative service delivery system between public and private firms within the same jurisdiction, using a mixed contract mechanism to improve service quality and reduce government financial burden. In the USA this mixed mode allows governments to compare the performance of public and private firms (Warner and Hefetz 2008). Under such a system, the most efficient firms receive awards and inefficient ones get penalized (Armstrong and Sappington 2006) and this has been shown in China (Zou and Chen 2009). Hefetz and Warner (2007) argue such mixed contracts give the chance to opt either to outsource further or to revert to public delivery, increasing the regulator's bargaining power over the concessionaires. When contracts to public firms and private firms are awarded through competitive tendering, this competitive environment creates pressure on both public and private firms, and this leads to increased concern for efficiency (Albalate et al. 2012). However, from 1980 to 2008, in some Chinese municipalities, like Shanghai, this mode did not have a good outcome (like in France, see Yvrande-Billon 2006). The main reason was that the local governments lacked effective ways of controlling the firms (Zhou 2009, Wei 2009). These

firms were profit-oriented. On the one hand, they invested in more lines and vehicles to the districts where large numbers of people lived. This increased access but also led to spatial disparity and dissatisfaction on the part of some residents. On the other hand, with the rise in oil prices, operation costs increased quickly, but the governments' subsidies could not cover the cost (Li 2008).

Fourth, public owner with business delivery mode balances the role of local governments, market and social groups based on network governance theory (as argued by Warner 2008). In this mode, public bus services are planned by a sector of local government and procured from independent business (either private or state-owned) under service contracts (similar to the approach described by Barter 2008). Moreover, this new mode involves social groups' participation. These social groups are consumer councils and expert groups with common interests in pursuit of high quality service. Their participation, investigation and consultation aim to protect public interest, improve efficiency and encourage user participation. Since 2009, Shanghai municipality has adopted the public owner with business delivery mode. It selected a mixed public-public firm to create a public firm as operator to deliver bus service. This is different from the mixed public-private firms found in Spain and Italy (Warner and Bel 2008, Bognetti and Robotti 2007). This mode involves public firm cooperation with the public sector to develop, maintain and operate public bus transport service, which results in a complex network. But the nature of the cooperation – as mixed firm or complex network – requires closer examination.

The nature of public owner with business delivery mode is that governments don't directly produce the service, but buy the service according to the terms of the contracts (Wang *et al*. 2010). This typically involves some kind of enterprise units within the public sector. The difference in the Chinese case is the greater government controlling stake in the firms. Governments give route franchise contracts to the public firms by the rules of private commercial law, such as the *The Company Law of the People's Republic of China (2006)*. In most cases, the contract is short term to prevent opportunistic behavior by concessionaires (as recommended by Albalate et al. 2012). The local government is responsible for planning the network and regulation. The public firms are responsible for their operation and management. Usually, the contract between government and operator is a gross-cost form, which means the revenue risk is borne by local government, and the production risk is borne by the operator. Or the contract is a net-cost form, which means both the revenue and production risks are borne by the operator. Under this circumstance, the operators are more independent to plan and operate than under the gross-cost form.

3 The case of Shanghai municipality bus service

3.1 The evolution of governance mode in Shanghai

Shanghai is one of the most developed cities in China. There have been two major reforms of the Shanghai municipality public bus service up to now. Each reform had a different governance mode.

In the planned economy period, from 1949 to 1996, Shanghai municipality bus service operated under the public owner with public delivery mode (e.g. pure public

production). There was only one state-owned firm to operate the bus service and the operator had full autonomy to manage its work force organization, purchase inputs, and so on, but these were controlled by government. The publicly-owned firms were similar to public bureaucracy. The result was that the enterprise had low efficiency. The government failed to raise bus fares with inflation, and the government's subsidies increased from 250 million RMB in 1992 to 800 million RMB in 1996.The Shanghai municipal government had to tackle the growing gap between its budget and the enterprise's demand for subsidy. The municipal government could not allocate more fiscal resources. During that period, China's governments were restructuring their state-owned enterprises and subjecting municipal utilities to market reforms.

Shanghai municipality began a market-oriented reform in public bus service in 1996. This reform was based on the New Public Management theory and implemented bus service privatization. During this period, the Shanghai municipality used the mixed owners with mixed delivery mode. Taking the number of firms as an example, there were more than 40 firms during the period of 1996 to 2008 in Shanghai. For example, in 2007, there were 8 public firms, 33 private firms and 2 foreign firms. They were awarded bus routes by a competitive tendering process. However, citizens were dissatisfied with the bus service. The reason was that private and foreign firms were profit-oriented and focused on the most profitable routes. The city government lacked effective ways to regulate them. This led to an uneven distribution of bus service across the geographical space of the city.

In 2009, the Shanghai municipality bus service was reformed again, which brought most of the previously contracted out services back in house in a process of reverse privatization. This wasn't a simple direct government monopoly as before. The difference was that the local government established a contract relation with the new public operators. Its reform was toward the public owner with business delivery mode. The current reform policy includes three parts. First, the city created *Shanghai Jiushi Company*, a public firm owned by Shanghai government, to supply the bus service. There are several reasons for this. The primary reason is China's market is imperfect. The privatization and outsourcing of public service had poor performance. Therefore, local governments were apt to select public firms to ensure public welfare. Second, the Shanghai municipality allocated more funds to the public bus field than before. These government fiscal funds focus on the fare and construction of infrastructural facility subsidies. These include both operation subsidies and construction subsidies. Third, Shanghai municipality issued more regulations on operators, such as *The Regulation of Shanghai Bus Transport Enterprises Costs*. This regulation includes the confirmation of cost components, the method of calculating cost and the reasonable cost scope. Shanghai municipality established an agency to calculate the enterprises' costs. The municipality also invites social experts to evaluate the public bus enterprise. Based on the experts' suggestions, government makes changes to its subsidy policy. Shanghai municipality bus service is now trying to balance government control, market and social group participation.

Performance improvement is a fundamental goal in the reform. Fig 1. shows that since the reform in 1996, the number of vehicles increased rapidly. This peaked in 2003, and then decreased. This change means that the partial privatization of mixed owners with mixed delivery mode stimulated quality improvements for a short time, but quality began to decrease and erode over time. After the second reform in 2009, where Shanghai bus service chose the public owner with business delivery mode, the number of vehicles

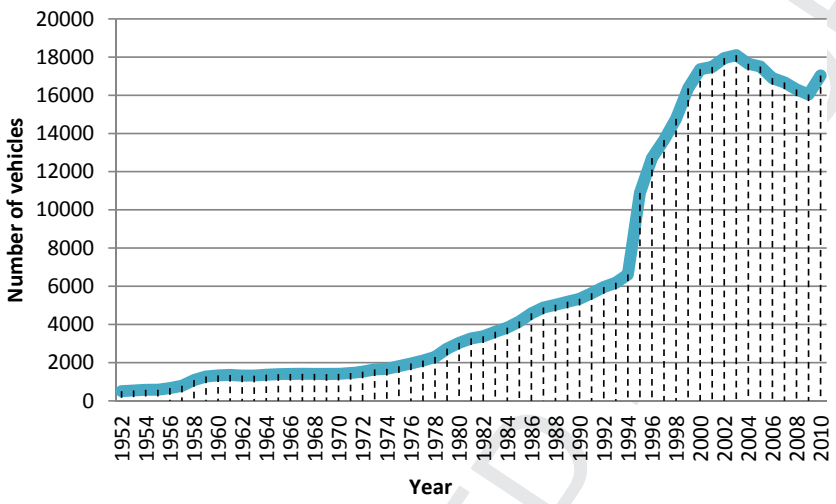

Figure 1 – Number of vehicles from the year of 1952 to 2010.
Source: Data collected from Shanghai Statistical Yearbook 1952–2011.

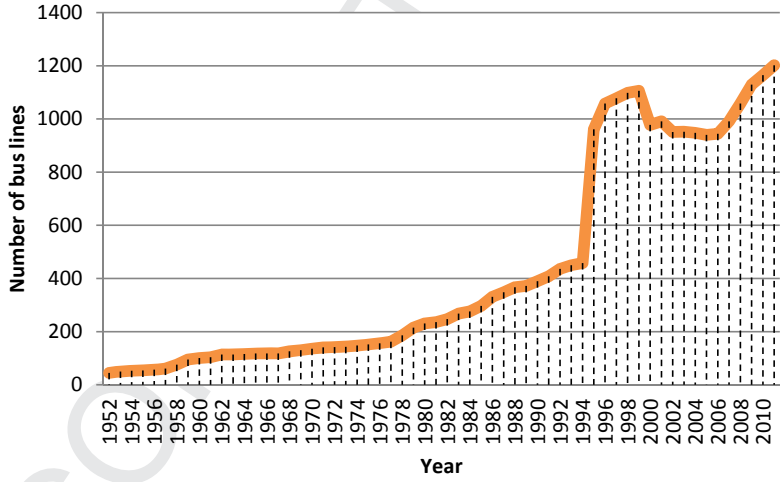

Figure 2 – Number of bus lines from the year of 1952 to 2011.
Source: Data collected from Shanghai Statistical Yearbook 1952–2012.

increased again. At the same time, the quality of vehicles also improved. It phased out more than 4100 old vehicles and bought more than 6000 new vehicles (including 614 new energy efficient vehicles) since 2008 (Chen 2012). These new vehicles helped reduce air pollution. From Fig. 2, we see that the mixed owners with mixed delivery mode had a higher efficiency than the public owner with public delivery mode, and the public owner with business delivery mode displays a better performance as regards vehicles and lines than before. Three years into the new reform (2009–2011), the numbers of bus lines rose to 1202, which is 144 more lines than in 2008. In addition, a benefit from the policy of public transport interchange concession, passengers' travel cost has decreased since 2009. In 2011, the average ticket price for every journey was 1.8 RMB, a drop of 17.8%

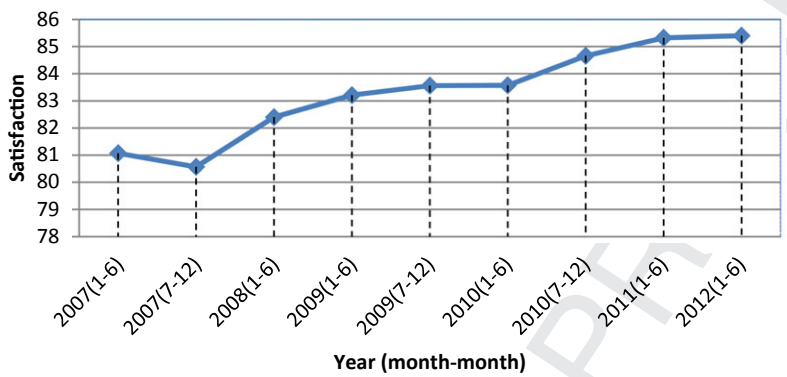

Figure 3 – Passenger satisfaction since 2007.
(The maximum satisfaction score is 100)
Source: Data collected from Customer Evaluation Center in Shanghai.

from 2008. At the same time, passenger satisfaction has increased since 2007 (See Fig 3.). Especially in 2008, the growth in passengers' satisfaction accelerated. According to the comparative information (more vehicles, more lines and higher satisfaction level, but lower ticket price), we see the reform in 2009 resulted in improved performance.

3.2 The current hybrid form in Shanghai

At present, the governance mode of Shanghai municipality bus service is public owner with business delivery. Its stakeholders are local government, bus operators and social groups, see Fig 4. from Wang and Zhu (2013). The *Municipal Transport and Port Authority (MTPA)* of Shanghai municipality is the transport authority, which is affiliated with the Shanghai municipal government. The *Public Transport Sector (PTS)* in the *MTPA* is the transport management department. The relation between *MTPA* and *PTS* is one of hierarchical control. *PTS* is directly responsible for implementing the urban public bus service's daily management and supervision. In addition, the *Municipal Traffic Administrative Law Enforcement Team (MTALET)* department in *MTPA* supervises the bus service together with *PTS*. The *MTPA* contracts with *Shanghai Jiushi Company (Jiushi Co.)*. *Jiushi Company* is an administrative enterprise of the bus service, which is controlled by the *State-owned Assets Supervision and Administration Commission of Shanghai Municipal Government*. The original *Jiushi Company,* which was owned by Shanghai government, merged with some other public owned companies in 2005 (e.g. *Shanghai Transportation Investment Group Co., LTD*; *Shanghai Ba-shi Industrial Co., LTD*; *Shanghai Wuqi Kwoon Chung Public Transport Co., LTD*). After the integration, the new *Jiushi Company* became a mixed public-public firm. In contrast to mixed public-private firms, the mixed public-public firm has some advantages. First, this kind of mixed firm has as a primary objective social welfare and public service maximization. Local government is a social planner and principal, and the mixed firm behaves as an agent of the principal. Second, according to the cooperation and integration among different public firms, the new mixed public-public firm could achieve economies of scale across

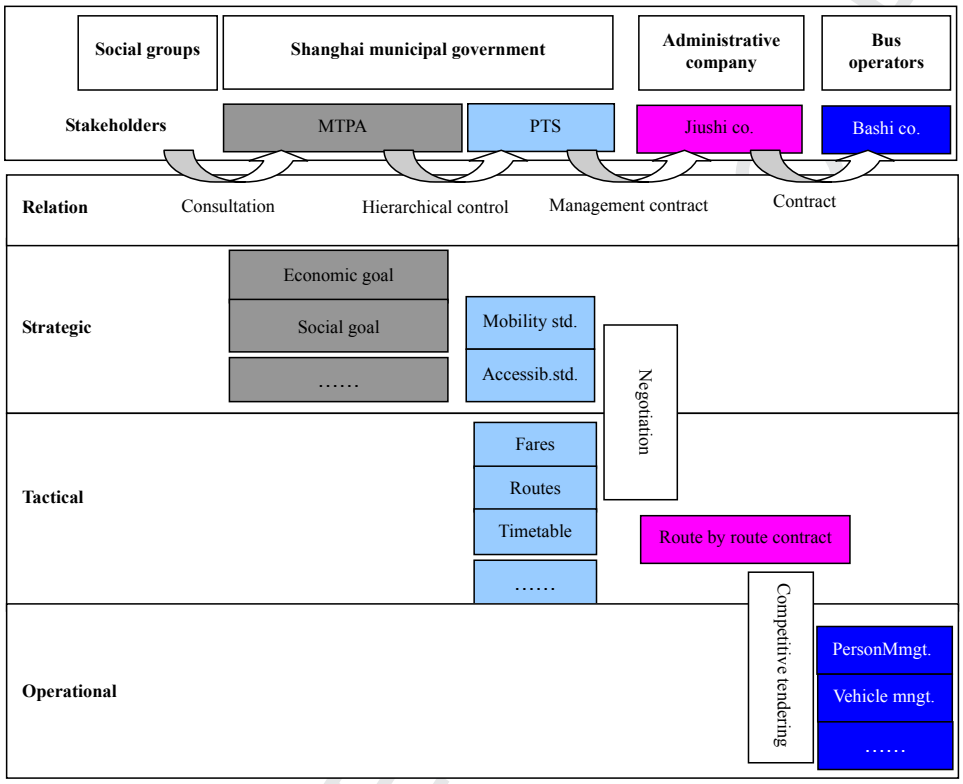

Figure 4 – Stakeholders and their responsibilities.

Source: WANG H. and ZHU D., 2013, 'Public owner with business delivery mode: the choice for reversing privatization', Journal of Northeastern University (Social Science), 15 (1), p 72.

the city. Third, local government trusts the local public firms and this could reduce the risk in principal-agent relational contracting.

The operator is *Shanghai Bashi Company (Bashi Co.)*, which was established in 2009. It is the *Jiushi Company*'s wholly-owned subsidiary company. The *Shanghai Bashi Company* also includes some subsidiary companies, such as *The First Bashi Company*, *The Second Bashi Company*, *The Third Bashi Company*, *The Fourth Bashi Company* and other subsidiary companies. These subsidiary companies have independent accounts and are responsible for their own profits or losses. They have different routes, but these subsidiary companies can share management experience and technical expertise from which all companies benefit. In addition, the financial information of these subsidiaries is regulated by *Jiushi Company*. And *Jiushi Company* is controlled by Shanghai government. This allows reduced monitoring costs.

According to van de Velde's concept of levels of planning and control (van de Velde 1999), there are strategic, tactical and operational level relations among stakeholders. The first level involves strategic planning. In Shanghai, the bus service development plan is organized by *MTPA*. However, the *MTPA* isn't capable of designing the transport plans by itself. *MTPA* encourages social groups to participate in its decisions making.

Usually, it invites some independent transport scientific research groups to do the job. These transport plans include economic goals, social goals and so on (Wang and Zhu 2013). These goals include such topics as the profit and market share aims, the area of supply and the description of the services (van de Velde 1999). They are developed in cooperation with government and operators, and social groups' participation can influence achievement of the goals. The plan must get the approval from the Shanghai municipal government.

The tactical level concerns decisions about how to reach the general goals. According to the bus service development plan, the bus routes, fares, timetable, vehicle types, number of vehicles and the maximum number of passengers are all checked and approved by *PTS* (Wang and Zhu 2013). These were embodied in *Shanghai Bus and Tram Service Specification*, which was issued and implemented in 2009. For instance, the bus lines' adjustment directly relates to the route residents' journey. However, the *PTS's* decision was top-down before 2008. *PTS* negotiated with experts, and then informed the citizens. But since 2008, *PTS* began to solicit local residents' advice. Shanghai government has realized that the inclusion of citizens' considerations in the design and delivery of bus service policy can be an important tool in the quest to increase performance and customer satisfaction.

Shanghai Jiushi Company gets the contract to operate the bus service through a negotiation process with *PTS*. *PTS* directly awards the contract to *Jiushi Company*, not by a tendering process with other companies (Wang and Zhu 2013). This creates a trust partnership between regulator and franchisee so the partners can achieve their common goals. Stanley (2010) researched this kind of trusting partnership in Melbourne city and emphasized the important role at the tactical level in helping to build a system to maximize the prospects for long-term goal achievement for government (the purchaser), service producers and users. In China, local government has greater power in this relationship.

The Shanghai bus service combines the negotiation approach (the relation between *PTS* and *Jiushi Company*) and the competitive tendering process (among the subsidiary companies of *Shanghai Bashi Company*). The subsidiary companies of *Shanghai Bashi Company* get the bus routes franchise through a competitive tendering process from *Shanghai Jiushi Company*. For example, *The First Bashi Company* got 56 routes by tendering, *The Second Bashi Company* got 77 routes, *The Third Bashi Company* got 53 routes and *The Fourth Bashi Company* got 50 routes. These subsidiary corporations competed with each other for these routes.

The operational level (the third level in van de Velde's (1999) schema) assures the orders are carried out in an efficient way. Subsidiary company operators execute the requirements in accordance with contract terms. Personnel management, vehicle maintenance and management are all the operators' responsibility (Wang and Zhu 2013). Taking personnel management for example, the subsidiary companies have their own employee management systems, but the top leaders of the subsidiaries are appointed by *Jiushi Company,* and the top leaders of *Jiushi Company* are appointed by government. During the operation period, the operators are supervised by MTALET (*Municipal Traffic Administrative Law Enforcement Team*) and evaluated by passengers and citizens. These new evaluation mechanisms were explicitly required by the law, *Regulations on the Bus and Tram Passenger Management of Shanghai City*, which was amended in

2010. The results evaluated by citizens and *MTALET* will be one criteria for government to award or cancel operator contracts.

Although the Shanghai bus service governance system is moving to public owner with business delivery mode, there are still some problems that need further discussion. Public participation is an example. There are two kinds of public participation in public service in China. There is participation in the *decision process* and participation in the *delivery process* (Wang 2011). In the *decision process*, there are three distinct phases for public involvement: *inform*, *consult* (government listens and incorporates parts of citizens' opinion) and *decision by the public*. In the *delivery process*, there are also three distinct phases for public involvement: *revise*, *improve* and *collaborate*. At present, social groups' participation in the Shanghai bus service is not enough; they are in the phases of *inform, consult, revise and improve*. For *decision by the public* and *collaborate* levels, government and operators don't cooperate with the social groups. Government, operator and social group have not constructed a strong cooperative relationship. Although the bus service development plan is organized by *MTPA* and some social groups, there are few operators involved. Generally speaking, the operators (*Bashi Co.*) have accumulated abundant practical experience. They could give practical advice to *MTPA*. Hence, it is necessary to increase stakeholder participation both of the operators and the social groups.

4 Discussion: stakeholders' rebalancing in the hybrid form

In the public owner with business delivery mode, local governments control the mixed public-public firms (different public companies mixed together, a hybrid form). The director and top manager of the board are guided by local government (in China, the leaders of public-owned enterprises have the administrative rank in the local governments), but the relations between government and operators are business contracts.

At the city-wide level the operator, *Jiushi Company*, gets the concession through negotiation. *Jiushi Company* then allows the *Bashi companies* to bid as operators for exclusive rights to operate service in specific routes for a specific period. These route concessions are competitively tendered. The objective of using a tendering procedure is to replace competition for the field by competition in the field, leading operators to operate public bus service at a competitive price without loss of quality (Amaral et al. 2009). The objective of using negotiation at the highest level (*Jiushi Company*) is to achieve a trusting partnership between government and operator, while remaining transparent, accountable and maintaining performance pressure on both of them (Stanley 2010). In the process of planning the route network and regulating operators, local government doesn't have enough capability to do those jobs. So the technical expert groups engage in the process, including the local governments' research institutes (such as the Shanghai Urban Transportation Design Institute, which is controlled by *MTPA*) and independent research groups. However, all major network-level activities and critical decisions are coordinated through and by local government similar to Provan and Kenis' (2008) coordinating center. To analyze the hybrid form, we study its two factors: the stakeholders and the approaches to balance the stakeholders.

4.1 Stakeholders

Public bus service is a complex governance system (Koppenjan and Klijn 2004). Its stakeholders are multiple actors, including local governments, bus operators and social groups. Much attention has been paid to the forms of co-operation between government and operator, while less is paid to the social groups, especially in China where markets are often distorted. These stakeholders are interdependent on each other, but there are power differences among them, with consumers and bus operators having less power than local government. They exchange resources, share knowledge and cooperate to solve common problems. The government sector acts as a leading organization in cooperation with the enterprises and social groups.

Local government is the arranger of bus service and is responsible for the interdependent network performance. China's national law requires that urban bus service be mainly dependent on local municipal provision. The government sector plays a lead role here as the primary organizer (Wang and Zhu 2013). In Shanghai, the bus stops are built by government. Operators can freely use them. The bus parking lots are also built by government. The government leases them to operators at a subsidized price. If operators update and renew their old vehicles, government will subsidize the vehicle purchase. The operator of public owner with business delivery mode, the mixed public-public firm (*Shanghai Jiushi Company*), is subject to government's macro-management and control through government regulation and contract design. The day-to-day operations are conducted by the subsidiary companies. This involves the performance measures clarified in the contract. Without specifying desired performance, such as outputs and outcomes, there is no way to say whether resources are sufficient or used effectively. In Shanghai, these performance indicators are expressly incorporated into the contracts. For example, the indicators include the timetable of the first-last bus and the departure time interval. At the end of 2011, the indicator of all bus lines compliance rate reached 100% (Chen 2012). As service recipients, social groups' power is increasing. There are many kinds of social groups. For example, in Shanghai there is a Customer Evaluation Center, an affiliate of SQCA (Standards and Quality Control Authority), which evaluates the bus service every quarter.

4.2 The ways to balance the stakeholders

The critical path to make the hybrid form work is to balance the three kinds of stakeholders. In traditional public administration, the approach to public service is to ensure that rules and appropriate procedures are followed. In the New Public Management, the approach is to help define and meet agreed upon performance targets (Stoker 2006). In the hybrid form, the approach is to find the common interests and cooperate in achieving collective goals by trust and incentive.

Trust is mentioned as one of the important success mechanisms for inter-organizational balance (Edelenbos and Klijn 2007). However, it is difficult to achieve joint decisions that balance actors in the public owner with business delivery mode (Wang and Zhu 2013). The reasons are that these stakeholders try to realize their own interests, and the contracts will never be complete in the sense that every single obligation is so clear that it can be written down *ex ante* (Hensher and Stanley 2010). In

Table 2 – Bus lines rectified and cancelled

Year	Lines rectified	Lines cancelled
2009	1	4
2010	5	0
2011	0	1
2012	0	0

Source: Data collected from MTPA

Shanghai, local government trusts *Jiushi Company* and uses this relationship to address problems of contract incompleteness. *Jiushi Company* is responsible for investment and construction in many public works (e.g. urban infrastructure) and it receives government contracts via negotiation.

What is clear from the reform is that it recognizes different stakeholders' interests and goals are different, thus it is necessary to implement different incentive tactics. For local government, the hybrid form holds the potential to balance the efficiency and effectiveness of bus service, which is what citizens' need (Wang and Zhu 2013). For operators, the contract incentive terms could increase performance. In Shanghai, the contract period is less than 8 years. The *Municipal Transport and Port Authority* evaluates the performance of operators every year and the maximum performance score is 100. If the score of an operator is less than 80 for 2 years in succession, then the operator's concession will be canceled. Then government would invite other operators to compete for the bus lines. If the score is more than 80, then the incumbent will be allowed to extend the contract. If the score is more than 90, then the operator is exempted from government examination. For example, the contracts of eight lines expired at the end of 2009. Three lines passed the examination and their contracts were extended. But one line was ordered to be rectified (improved) and four lines were cancelled due to poor performance. Cancelled lines will be awarded to other companies. See Table 2.

For social groups, they can benefit from the incentive tactics of participation. *Shanghai Municipal Transport and Port Authority* is giving more weight to social groups to evaluate the performance of bus operators. The feedback from passengers, news media, and experts are important components in the performance examination index. Every year, Shanghai government entrusts the Customer Evaluation Center to conduct a passenger satisfaction survey. The extent to which this new governance mode actually results in improved performance remains to be seen. But we have attempted to clarify the core elements of the reform in our review.

5 Conclusion

The last six decades witnessed a cyclical tendency in China's public bus service governance regulation. There are some distinct factors and drivers that influence the governance choice. These factors are stakeholders and their relations in the governance cycle. The public owner with public delivery mode, private owner with private delivery mode, and mixed owners with mixed delivery mode lacked balanced relations among government, operators and social groups. Either government has more

power, or operators have more power. The results of this imbalance were that those bus service modes were failures. Therefore some cities in China, like Shanghai, have chosen the public owner with business delivery mode, which focuses on balancing government planning, market and social groups' participation. In the public owner with business delivery mode, stakeholders clearly know their own responsibility and duty. This is a cooperative network governance organization, and local government plays a lead role in it. China's reality is that municipal government has stronger power and more resources than market and social groups. Publicly owned firms are playing important roles in the public service market and most of them are owned by local governments. On the one hand, their decisions and behaviors are influenced by local government. On the other hand, they also need to pursue efficient service to maximize their returns. Although their bus fare is regulated by governments, they can implement management reforms (such as *the Regulation of Shanghai Bus Transport Enterprises Costs*) to improve efficient and reduce cost. The cooperation mechanisms between the members of the network are both trust and incentive based (such as extending contracts).

The public owner with business delivery mode and the mixed public-public firms play an increasingly significant role in several cities of China, such as *Shanghai*, *Guangzhou*, *and Changsha*. Although it remains unclear whether this new hybrid governance form could replace other governance modes or be widely used in other cities, it gives us additional insights and information to better analyze the dynamics of reform in the urban bus transport sector. The case also raises important similarities and differences with the mixed public-private firms we are seeing emerge primarily in Europe. In both cases, the hybrid reform is an effort to instill market discipline but maintain public control to ensure quality public service is delivered to residents. Challenges of information asymmetries, power differentials, goal congruence and regulatory versus trust or incentive based mechanisms are at the core of the mixed firm, mixed network approach to public service delivery reform.

REFERENCES

ALBALATE D., BEL G. and CALZADA J., 2012, 'Governance and regulation of urban bus transportation: using partial privatization to achieve the better of two worlds', *Regulation & Governance*, 6, 1, 83–100.

AMARAL M., SAUSSIER S. and YVRANDE-BILLONA., 2009, 'Auction procedures and competition in public service: the case of urban public transport in France and London', *Utilities Policy*, 17, 2, 166–175.

ARMSTRONG M. and SAPPINGTON D., 2006, 'Regulation, competition and liberalization', *Journal of Economics Literature*, 44, 2,325–366.

BARTER P.A., 2008, 'Public planning with business delivery of excellent urban public transport', *Policy and Society*, 27, 2, 103–114.

BLOKLANDM W., BRAADBAART O. and SCHWARTZ K., 1999, *Private Business, Public Owners: Government Shareholdings in Water Companies*, Ministry of Housing, Spatial Planning and the Environment, The Hague: Netherlands.

BOGNETTI G. and ROBOTTI L., 2007, 'The provision of local public services through mixed enterprises: the Italian case', *Annals of Public and Cooperative Economics*, 78, 3, 415–437.

CHEN Y., 2012, 'Deepening the reform of public transportation in Shanghai achieved remarkable results', *Traffic & Transportation*, 5, 19–21 [in Chinese].

CHONG E., SAUSSIER S. and SILVERMAN B.S., 2012, 'Water under the bridge: city size, bargaining power, prices and franchise renewals in the provision of water', paper presented in honor of Oliver Williamson, Berkeley, CA.

CLIFTON J. and DIAZ-FUENTES D., 2010, 'Evaluation EU policies on public service: a citizens' perspective', *Annals of Public and Cooperative Economics*, 81, 2, 281–311.

CRUZ N.F. and MARQUES R.C., 2012, 'Mixed companies and local governance: no man can serve two masters', *Public Administration*, 90, 3, 737–758.

EDELENBOS J. and KLIJN E.H., 2007, 'Trust in complex decision-making networks: a theoretical and empirical exploration', *Administration & Society*, 39, 1, 25–50.

GWILLIAM K., 2008, 'Bus transport: Is there a regulatory cycle', *Transportation Research Part A*, 42, 9, 1183–1194.

HALL D., LOBINA E. and TERHORST P., 2013, 'Re-municipalisation in the early twenty-first century: water in France and energy in Germany', *International Review of Applied Economics*, 27, 2, 193–214.

HEFETZ A. and WARNER M.E., 2007, 'Beyond the market vs. planning dichotomy: understanding privatization and its reverse in US cities', *Local Government Studies*, 33, 4, 555–572.

HENSHER D.A. and STANLEY J., 2010, 'Contracting regimes for bus services: what have we learnt after 20 years', *Research in Transportation Economics*, 29, 1, 140–144.

HUANG J. and YE L., 2011, 'The institution choice logic of reversion of contracting out in public service delivery: the case of garbage collection service in Guangzhou, China', *Journal of Public Administration*, 5, 100–120 [in Chinese].

KOPPENJAN J.M.F. and KLIJN E.H., 2004, *Managing Uncertainties in Networks*, Routledge, New York.

LI Y., 2008, 'Research on the institution transition of urban utilities subjects in China', *Modern Business Trade Industry*, 7, 101–102 [in Chinese].

PROVAN K.G. and KENIS P., 2008, 'Modes of network governance: structure, management and effectiveness', *Journal of Public Administration Research and Theory*, 18, 2, 229–252.

RAMESH M., ARARAL E. and WU X., 2010, *Reasserting the Public in Public Service: New Public Management Reforms*, Routledge, London.

SCHMITZ P.W., 2000, 'Partial privatization and incomplete contracts: the proper scope of government reconsidered', *Finanz Archiv*, 57, 4: 394–411.

STOKER G., 2006, 'Public value management: a new narrative for networked governance', *American Review on Public Administration*, 36, 1, 41–57.

STANLEY J., 2010, 'Goal achievement with trusting partnerships at the tactical level', *Research in Transportation Economics*, 29, 1, 99–105.

VAN DE VELDE D.M., 1999, 'Organizational forms and entrepreneurship in public transport', *Transport Policy*, 6, 3, 147–157.

VEENEMAN W., 2010, 'Changing public transport governance in Dutch metropolis: to tender or not to tender', *Research in Transportation Economics*, 29, 1, 195–203.

WANG J., 2011, 'Research on public participation mode in public service', *Journal of Political Science*, 4, 51–58 [in Chinese].

WANG H., ZHU D. and WU G., 2010, 'Choice of public transport modes', *Urban Problem*, 10, 45–49 [in Chinese].

WANG H. and ZHU D., 2013, 'Public owner with business delivery mode: the choice for reversing privatization', *Journal of Northeastern University (Social Science)*, 15, 1, 68–74 [in Chinese].

WARNER M.E., 2008, 'Reversing privatization, rebalancing government reform: market, deliberation and planning', *Policy and Society*, 27, 2, 163–174.

WARNER M.E. and BEL G., 2008, 'Competition or monopoly? Comparing privatization of local public services in the US and Spain', *Public Administration*, 86, 3, 723–735.

WARNER M.E. and HEFETZ A., 2008, 'Managing markets for public service: the role of mixed public-private delivery of city services', *Public Administration Review*, 68, 1, 155–166.

WARNER M.E. and HEFETZ A., 2012, 'Insourcing and outsourcing: the dynamics of privatization among U.S. municipalities 2002–2007', *Journal of the American Planning Association*, 78, 3, 313–327.

WEI J., 2009, 'Privatization and government regulations of urban public traffic: tracking Lanzhou city as an example', *Chinese Public Administration*, 6, 88–91 [in Chinese].

YVRANDE-BILLON A., 2006, 'The attribution process of delegation contracts in the French urban transport sector: why is competitive tendering a myth', *Annals of Public and Cooperative Economics*, 77, 4, 453–478.

ZOU D., 2009, 'Public service privatization is not government responsibility privatization', *Theoretical Investigation*, 4, 151–154 [in Chinese].

ZOU D. and CHEN Y., 2009, 'The mixed mode is the choice for public bus service privatization reform', *Theoretical Investigation*, 4, 84–88 [in Chinese].

ZHOU Z., 2009, 'New perspectives on market-oriented reforms', *Chinese Public Administration*, 3, 11–16 [in Chinese].

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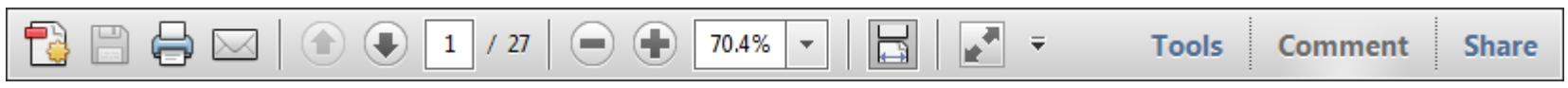

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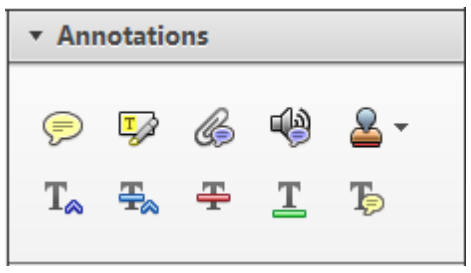

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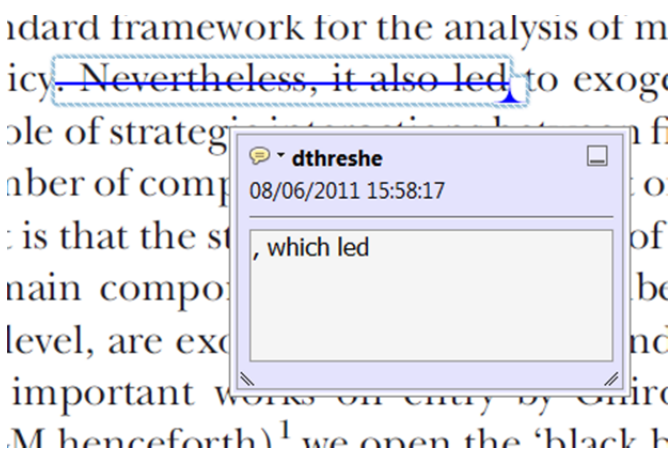

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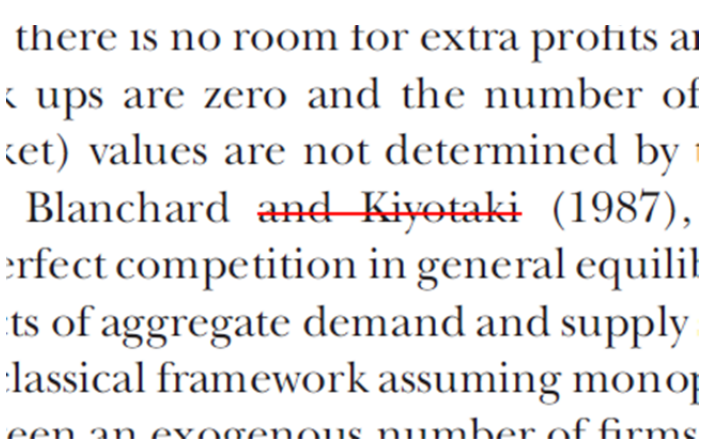

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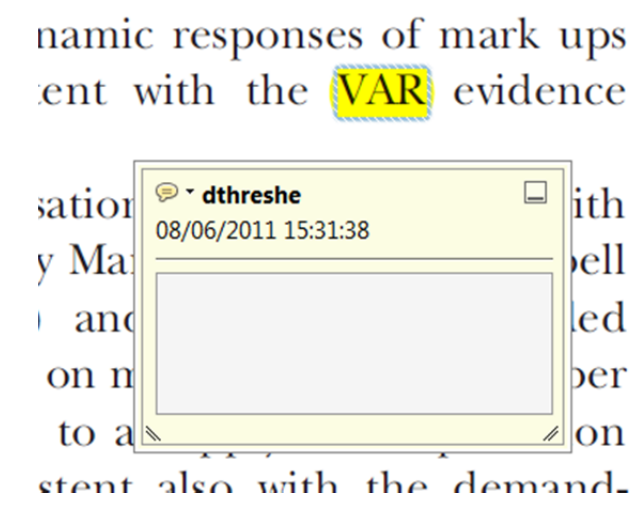

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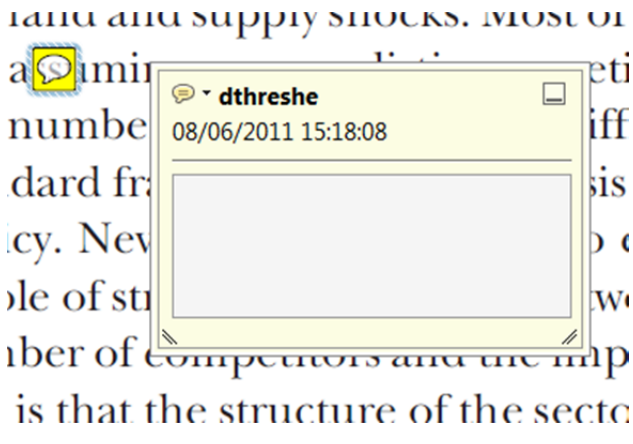

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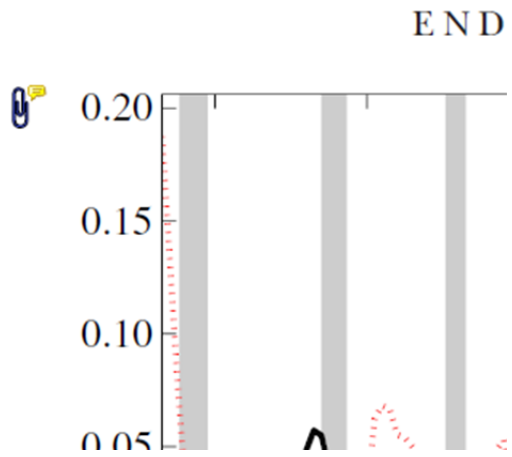

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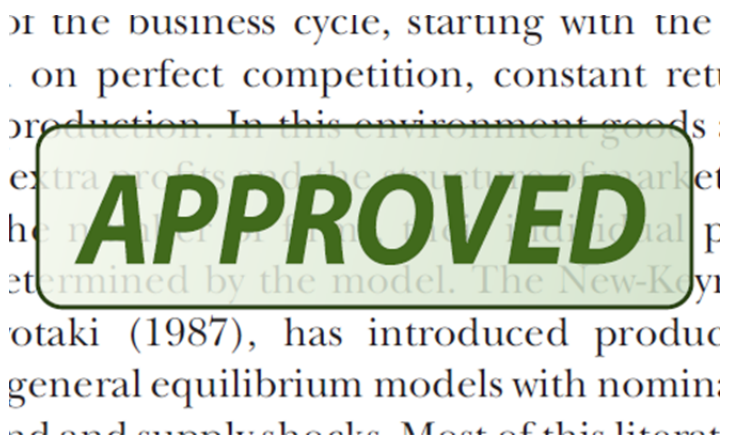

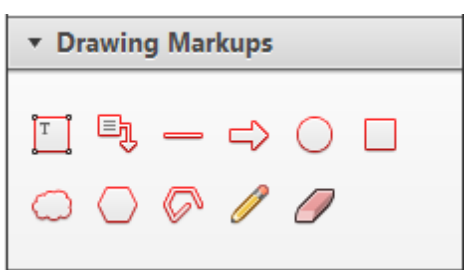

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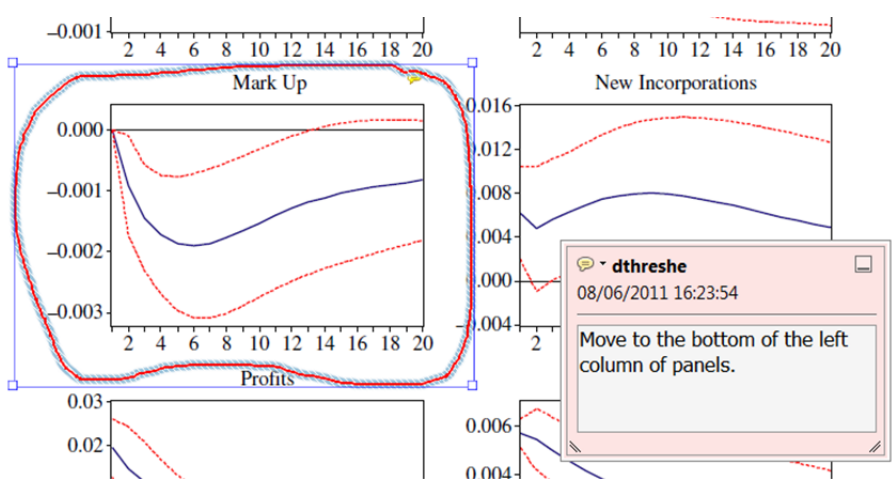

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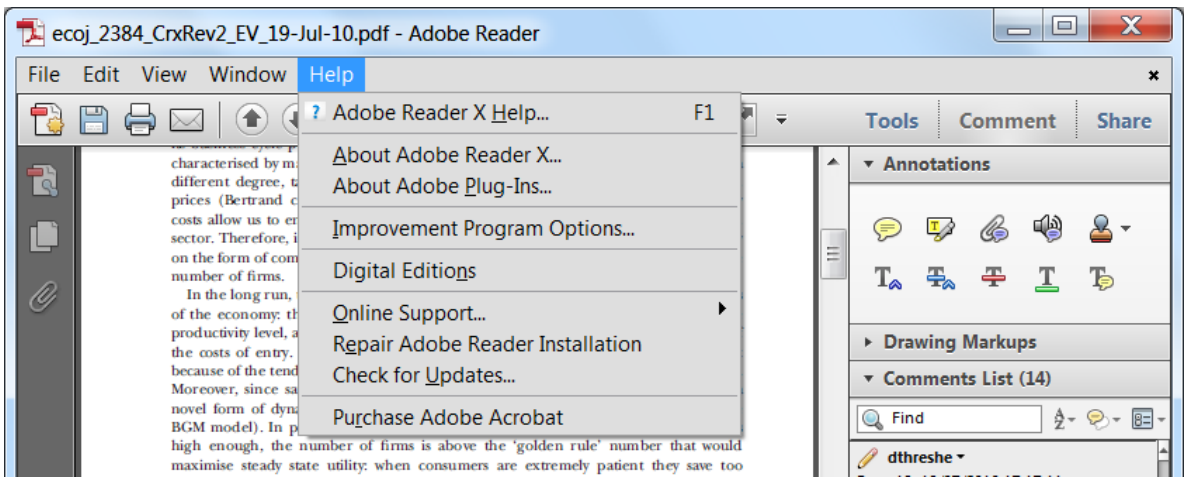

中国主要粮食作物的水足迹值: 1978 – 2010

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摘要 水足迹是度量水资源利用效率改进的工具,中国农业的水资源紧缺使计算从单一粮食作物到国家等不同层面的水足迹值的重要性凸显。文章基于彭曼公式对单种粮食作物绿水和蓝水水足迹值进行计算,介绍了省际范围、国内生产、国际贸易以及国内消费水足迹值的计算方法,测算了 1978 – 2010 年共 33 年内的稻谷、小麦、玉米、大豆和高粱等 5 种主要粮食作物的上述 4 种水足迹值。结果表明: 33 年间中国稻谷种植消费了 48% 的水足迹值,是水足迹消费量最大的粮食作物。相对于绿水更加稀缺的蓝水在此期间利用效率提高了 40%,而中国国内生产粮食作物水足迹总量却不降反升,2010 年比 1978 年增长了 2.01%。中国是 5 种粮食作物的水足迹净进口国,并且对国外的水足迹依赖程度正在增大,进口粮食作物水足迹量在国内消费水足迹值中的占比从 1978 年的 1.67% 增加至 2010 年的 9.06%。在进口的水足迹中,绿水足迹与蓝水足迹的比例为 14.06,高于国内 1.96 的比例,表明其他国家将其相对丰富的雨水通过粮食贸易出口给中国,缓解了中国国内的水资源稀缺,提高了国际水资源的利用效率。最后,对比水足迹与土地、人口和经济发展关系发现,33 年间种植单位面积的粮食作物例如稻谷所需要的水足迹量降低了 37.58%,人均水足迹量降低了 13.54%,单位水足迹的经济产出提高了 9.89%,而之所以水足迹的综合利用效率的提高没有带来水足迹总量的减少,主要原因由于 5 种粮食作物产量在其间增加了 98.89%,粮食种植数量增加了水足迹总量。

关键词 水足迹; 农业; 粮食作物; 彭曼公式; CropWat 软件

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水足迹是指个人、企业或国家生产产品或者消费服务过程中消耗的水资源和为了稀释污染水达到排放标准所需要的水资源量的总和[1]; 它分为绿水、蓝水和灰水 3 种, 3 种水足迹分别代表雨水、淡水以及生产过程中产生的污水数量。水足迹从技术角度衡量水资源的使用效率,量化了全过程中产生的水污染。国外的水足迹研究已有 10 年历史并且研究正日趋完善,与此相比我国的研究还处于起步阶段[2],尚没有出现针对中国粮食作物水足迹的系统性研究,包括对计算方法、数据来源等的详细阐述。本文梳理了此前水足迹计算的相关国内外文献,述评了已有的计算方法和计算案例。在详细介绍了计算中采用的方法和数据来源后,本文运用彭曼公式计算了全国各个省份和直辖市 1978 – 2010 年间的 5 种主要的粮食作物稻谷、小麦、玉米、大豆和高粱的绿水和蓝水足迹值。计算结果发现 33 年间水足迹与人口、经济效益和土地等其他自然资源的综合使用效率提高; 我国的国内生产、国际贸易以及国家最终消费的水足迹总量仍在上升。

1 文献回顾

2002 年水足迹概念提出[3],如今已经有 10 年的研究历史。其研究分为几个阶段,第一阶段是 2002 – 2008 年,水足迹的研究集中计算方法探讨和数值计算上。Hoekstra 首先提出了水足迹的初步计算方法[4],随后他的研究团队逐步完善了绿水、蓝水和灰水足迹计算方法。在此基础上可以计算不同地理以及活动范围内的水足迹: 小到种植一株作物、生产某种商品、一个或者多个消费者、一个地区、一个国家的水足迹,大到全球[1]。水足迹的计算方法有自下而上和自上而下两种,分别称为全生命周期法和投入产出法; 全生命周期法常用于基础性产品如农产品水足迹值的计算,而投入产出法则用于较大范围水足迹值的计

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算[4]。为了将计算过程程序化,现在已经在完善计算参数的基础上开发了模型、建立了数据库,如 CropWat 和 AquaCrop 等数据库可用于计算水足迹,CropWat 模型由联合国粮农组织建立、适用于理想状况,缺水条件下 AquaCrop 模型更适用[5]。蓝水计算最佳数据来源是产品制造商掌握的数据或者由当地政府以及全球性的分支机构提供的数据[1]。按照计算范围、水足迹类型和行业的不同可以将水足迹计算细分。小的计算范围可以是一种农作物、一次活动等。如对小麦水足迹计算过程中需要的参数数据的研究,可以供世界其他地区小麦水足迹计算参考[6-9]。计算范围大到一省或者一个国家,如印度、印度尼西亚和西班牙各省份的水足迹值,英国国家水足迹总量[10-12]。水足迹有绿水、蓝水和灰水 3 种。针对绿水和蓝水足迹,世界各国家不同农作物生长所需绿水和蓝水足迹被计算出来,并被公布在"世界水足迹网络"网站上[1]。与绿水和蓝水计算相比,灰水计算因为需要实时数据因此计算相对复杂,数据可得性较差。但是由于灰水足迹能够直接反应生产过程中的污染程度,因此也有学者在数据可获范围内展开了对灰水足迹的研究[8,12-14]。从行业来看,农业水足迹的研究最多,工业水足迹的计算也已经出现,并且研究结果能够为工业生产提供很多启示。如通过对饮料包装盒生产过程的研究发现从饮料盒原料生产到饮料盒到达消费者手中的过程中,供应链水足迹占比 99.7% –99.8%;因此,为了减少水足迹总量,相对于提高生产环节的水资源使用效率,供应链环节的水资源使用效率的提高是减少水足迹值的关键[15]。

对水足迹影响因素的研究建立在水足迹值计算的基础上。研究证明经济、贸易以及人口因素是影响一个国家或者地区水足迹值的重要原因[16]。国内学者计算了中国不同省份、区域的水足迹值,并对影响水足迹值的因素进行了分析[17],模拟了未来不同的贸易政策和水资源使用技术条件下的水足迹值[16-17]。

综上所述,学者将注意力集中在欧洲、中东、北非、印度等国家的农产品水足迹研究上[10,18],针对中国农产品尤其是粮食产品水足迹研究非常少见。有几篇中国粮食产品水足迹值计算出现[19-20],却没有系统介绍粮食产品水足迹的计算过程,包括计算方法、计算中所需要的数据如何进行查找,如何使用计算软件将数据计算出来等。因此本文尝试对中国粮食产品水足迹值进行系统计算,以期将水足迹工具应用在中国粮食产品耗水量的计算中。

2 计算方法

本文的计算建立在彭曼公式的基础上,该公式用于计算某一种粮食作物的单位质量需水量,在此基础上可以得到该种粮食作物单位质量的绿水和蓝水足迹值。随后,根据各省级行政区域内的粮食作物产量计算各省份的水足迹值,将上述数值加总即为国内生产粮食作物水足迹值;加上通过国际贸易所得到的粮食作物水足迹净值,两者之和即国内消费粮食产量的水足迹总量。

2.1 单位质量粮食作物需水量计算

本文计算理想种植条件下的粮食作物绿水和蓝水需要量。

区域 n 内作物 c 的单位质量需水量 CWR 等于区域 n 内作物 c 的单位面积需水量 CWU 与区域 n 内作物 c 的单位面积产量 CY 之比。种植单位面积作物的需水量 CWU 等于生长周期内的蒸发累积数量 ET 的 10 倍。由于 CropWat 软件中得出的作物需水量单位为 mm,因此将其乘以倍数 10 将单位转换为 m^3/hm^2。作物系数 K_c 与参考作物蒸发蒸腾水量的乘积 ET_0 即蒸发系数 ET,在这里作物系数 K_c 反应粮食作物本身的生物特性(如叶面积、蜡质层、产量水平、土壤、栽培条件)对需水量的影响。

$$CWR = CWU/CY \tag{1}$$

$$CWU = 10 \times \sum_{d=1}^{lgp} ET \tag{2}$$

$$ET = K_c \times ET_0 \tag{3}$$

公式中 CWR,CWU,CY,ET,K_c 和 ET_0 分别表示作物单位质量需水量(m^3/t)、单位面积需水量(m^3/hm^2)、单位面积产量(t/hm^2)、蒸发系数(mm/d)、作物系数和参考作物蒸发蒸腾水量(mm/d)。

参考作物蒸发蒸腾水量 ET_0 运用标准彭曼公式求解,该公式由联合国粮农组织(FAO)推荐并修正。它忽略了作物类型、作物发育和管理措施等因素,仅考虑气象参数对农作物需水的影响。

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} V_2 (p_a - P_d)}{\Delta + \gamma(1 + 0.34V_2)} \tag{4}$$

其中,R_n 地面净辐射蒸发当量($MJ\ m^{-2}\ d$);G 土壤热通量($MJ\ m^{-2}\ d$);γ 温度计常数(kPa^0C^{-1});T 平均气温(℃);V_2 2m 高的风速(ms^{-1});p_a 饱和水气压(kPa);p_d 实际水气压(kPa);$p_a - p_d$ 饱和水气压与实际水气压(kPa);Δ 温度 – 饱和水气压曲线的斜率($kPa℃^{-1}$)。

2.2 单位质量粮食水足迹

单位质量作物绿水需要量 ET_{green} 在农作物生长过程中的蒸发水量 ET_c 和有效降水量 P_{eff} 中取较小值。在理想种植条件下,粮食作物蒸发水量 ET_c 等于单位质量作物需水量 CWR。

单位质量作物蓝水足迹 ET_{blue} 的数值由绿水足迹 ET_{green}、灌溉需水量 I_r 和有效灌溉供水量 I_{eff} 决定。灌溉需水量 I_r 是作物需水量 ET_c 与绿水足迹 ET_{green} 的差值;如果

绿水足迹量就能够满足作物生长所需，那么粮食作物不需要灌溉，蓝水足迹数为零；否则 ET_{blue} 在灌溉需水量 I_r 和有效灌溉供水量 I_{eff} 中取较小值。

$$ET_{green} = \min(ET_c, P_{eff}) \quad (5)$$

$$ET_c = CWR \quad (6)$$

$$I_r = ET_c - ET_{green} \quad (7)$$

$$ET_{blue} = \min(I_r, I_{eff}) \quad (8)$$

公式中 ET_{green}，ET_c，P_{eff}，I_r，ET_{blue} 和 I_{eff} 代表单位质量作物绿水足迹（m^3/t）、农作物生长过程中的蒸发水量（m^3/t）、有效降水量（m^3/t）、灌溉所需水量（m^3/t）、单位质量作物蓝水足迹（m^3/t）和有效灌溉供水量（m^3/t）。

2.3 国内生产粮食的水足迹

各个省份或者直辖市的一年内绿水和蓝水足迹之和是该年份的国内生产水足迹总量，计算中国粮食作物水足迹时选取了稻谷、小麦、玉米、大豆和高粱 5 种主要的粮食作物求其水足迹的值；计算地理范围包括除去台湾、香港和澳门之外的 31 个省、自治区和直辖市。

$$WF_N = \sum_{i=1}^{n} C_i \times ET_i \quad (i = 1, 2, 3, \ldots n) \quad (9)$$

公式中 WF_N，C_i 和 ET_i 分别代表某一省或者直辖市省份绿水或者蓝水足迹总量（m^3）、某省份一种粮食作物年产量（t）、某省份某种粮食作物单位水足迹值（m^3/t）。

2.4 国际贸易粮食水足迹

一国通过粮食进出口贸易与其他国家进行水足迹的交换，其进口水足迹总量减去出口水足迹总量，即为一个国家粮食贸易的进口水足迹净值。进口粮食产品单位水足迹取国际平均值[13]，出口粮食产品水足迹值采用公式（1）-（8）中的计算值。进出口的粮食产品数量是原生粮食作物的数量，不包括加工产品。

$$WF_T = WF_I - WF_E \quad (10)$$

$$WF_I = ET_{average} \times Q_I \quad (11)$$

$$WF_E = ET_{green/blue} \times Q_E \quad (12)$$

WF_T，WF_I，WF_E，$ET_{average}$，Q_1 和 Q_2 分别代表进口水足迹净值（m^3）、进口粮食作物水足迹值（m^3）、出口粮食作物水足迹值（m^3）、粮食作物国际平均水足迹值（m^3/t）、进口粮食产品数量（t）和出口粮食产品数量（t）。

2.5 国家消费水足迹总量

一国最终消费的粮食产品水足迹值，由国内生产与国际贸易两部分组成。国内生产水足迹是这个国家所有省份和直辖市生产量的加总；进出口水足迹值是这一年的进口粮食产品水足迹值减去出口粮食产品中所包含水足迹的差值。

$$WF_C = WF_N + WF_T \quad (13)$$

WF_C 即一国最终消费的粮食产品水足迹值（m^3）。

2.6 计算软件

本文采用 FAO 设计的 ClimWat 和 CropWat 软件计算农作物生长过程中的绿水和蓝水需要量。ClimWat 能够提供 CropWat 计算所需要的城市气象数据，是计算过程中的辅助软件；在这个软件中找到相应城市的气象站点，然后将数据导出，用主要软件 CropWat 读出来。CropWat 是依据标准彭曼公式设计的，在本文中它可以算出如下三项：生长周期内给定气候条件下的需水量；生长周期内的有效降水量；灌溉需水量。

3 数据来源及统计

3.1 数据来源

本文的计算中各个气象站点的气象数据最低和最高温度、湿度、风速、光照时间、辐射强度、参考作物蒸发蒸腾水量、每月降雨量和每月有效降雨量等来自于 FAO 的软件 ClimWat。作物数据信息参考 Allen 的文章同时结合本地作物实际生长信息[21]。土壤结合当地土壤类型从 FAO 全球数据库中找到与此类型对应的土壤信息（FAO）。农作物根茎长度、临界损耗水平以及产出影响因素从 FAO 全球数据库中查找。除青海省外，各省份气象和作物生长数据以该省省会为准；青海省省会西宁市的数据在 ClimWat 软件中没有列出，选取都兰市作为代表城市。

各个省份以及直辖市中粮食作物年产量、单位面积产量数据，中国粮食作物总产量和单位面积产量源于《中国农业统计资料》、《改革开放三十年农业统计资料汇编》、《中国粮食统计年鉴》和各省统计年鉴。中国粮食产品贸易量源自 FAO 数据库和《中国农产品商品年鉴》。

3.2 数据描述性统计

3.2.1 国内数据

在中国，稻谷、小麦和玉米是产量居于前 3 位的粮食作物。本文选取稻谷、小麦、玉米、大豆和高粱 5 种粮食作物作为研究对象，它们是我国的主要粮食作物，其产量总和在粮食作物总产量中占比在 92% 以上。因此选取这 5 种粮食作物水足迹作为中国粮食作物水足迹的研究对象，其数据具有代表性。

1978－2010 年间，稻谷年平均产量 1.77×10^8 t；产量最高值是 1997 年的 2.00×10^8 t，最低值是 1978 年的 1.37×10^8 t。小麦年平均产量 9.35×10^7 t；最高产量出现在 1997 年的 1.23×10^8 t，最低值是 1978 年的 5.38×10^7 t。玉米年平均产量 1.04×10^8 t；最高产量出现在 2010 年的 1.77×10^8 t，最低值是 1994 年的 5.59×10^7 t。大豆年平均产量 1.27×10^7 t；最高产量出现在 2004 年的 1.74×10^7 t，最低值是 1979 年的 7.46×10^6 t。高粱年平均

产量 3.01×10^5 t; 最高产量出现在 1998 年的 4.09×10^6 t, 最低值是 2009 年的 1.68×10^6 t。

3.2.2 进出口数据

1978 – 2010 年间中国主要粮食作物稻谷、小麦、玉米、大豆和高粱的进口数量减去出口数量的差值即其净进口数量,这 5 种粮食作物年均净进口数量依次为 -9.00×10^5 t, 7.03×10^6 t, 4.65×10^5 t, 1.09×10^7 t 和 6.97×10^4 t。

(1) 稻谷,平均每年出口 1.30×10^6 t,进口 4.00×10^5 t; 1994 年出口数量最多,为 1.70×10^4 t; 1978 – 1985 年间出口数量为零; 进口最大值是 2009 年的 1.65×10^6 t; 最小值是 1978 – 1985 年和 1997 年,数量为零。

(2) 小麦,平均每年出口 4.89×10^5 t,进口 7.52×10^6 t; 出口最大值是 2007 年的 2.34×10^6 t,最小值是 1978 – 1985 年,数量为零; 进口最大值是 1985 年的 1.574×10^7 t,最小值是 2008 年的 1.01×10^6 t。

(3) 玉米,平均每年出口 4.42×10^6 t,进口 4.89×10^6 t; 出口最大值是 2003 年的 1.64×10^7 t,最小值是 1978 年的 3.00×10^4 t; 进口最大值是 1995 年的 1.17×10^7 t,最小值是 2010 年的 1.57×10^6 t。

(4) 大豆,平均每年出口 5.32×10^5 t,进口 1.14×10^7 t; 出口最大值是 1987 年的 1.71×10^6 t,最小值是 1978 年的 1.13×10^5 t; 进口最大值是 2010 年的 5.48×10^7 t,最小值是 1978 年的 1.15×10^6 t。

(5) 高粱,平均每年出口 1.67×10^5 t,进口 2.40×10^5 t; 出口最大值是 1989 年的 9.01×10^5 t,最小值是 1978 年,数量为零; 进口最大值是 1981 年的 8.40×10^5 t,最小值是 1992 年的 2.29×10^4 t。

上述 5 种粮食作物进出口水足迹数值取世界平均水足迹[13]。

4 计算结果与分析

4.1 全国水足迹总消费量

我国是世界粮食第一大生产国,但却是粮食净进口国家而非粮食出口国; 随同粮食进口到我国的还有其他国家的水资源。由图 1 看出,我国自改革开放以来,一直在进口其他国家的粮食生产中的水资源。在 2003 年之后,5 种粮食产品的净进口水足迹数值增幅攀升; 我国进口粮食水足迹在水足迹消耗总量中的占比从 1978 年的 1.67% 增至 9.06%,总量从 1.78×10^9 t 增加至 1.18×10^{10} t。其直接原因是入世之后我国从其他国家进口了大量粮食产品,我国粮食市场对国际粮食市场的依赖程度增加。同时入世后工业生产以及出口贸易的发展也使我国自身生产越来越多的粮食,因此我国国内粮食生产所消耗的水足迹以及最终消费的粮食产品水足迹同期增长。

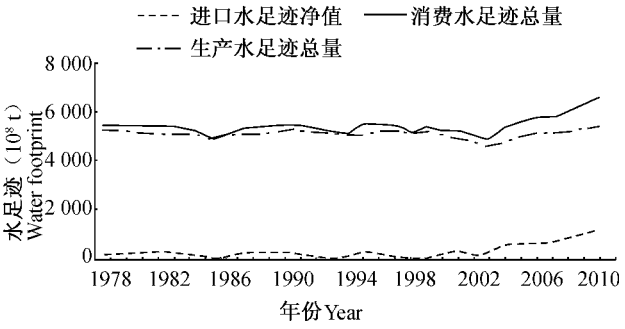

图 1 中国主要粮食作物水足迹数量(1978 – 2010)

Fig. 1 Water footprint of Chinese main food crops (1978 – 2010)

近 15 年间我国粮食作物水足迹总量曾出现两次明显的波谷值,第 1 次是 1998 年,当时爆发的大洪水袭击了东北、华北、长江流域和珠江流域,使国内粮食生产受损、进口贸易受影响,这一年进口水足迹净值、生产水足迹总量和消费水足迹总量比上年减少 29.24%, 4.09% 和 4.69%。第 2 次是 2003 年, "非典"公共卫生事件使粮食生产受挫,国内生产水足迹值下降了 4.40%。

4.2 国内水足迹生产量

4.2.1 各省级行政区水足迹值

在粮食作物的生产中,绿水来自降水,而蓝水则是地下或者地表水资源,蓝水的可再生性弱于绿水。因此,考察 33 年间各省份水足迹数量时,以年平均蓝水足迹升序作图 2。除了宁夏和新疆两个省份之外,各个地区的年均绿水普遍高于蓝水数量,说明降水是粮食种植依赖的重要水资源来源。图中蓝水足迹消耗后 10 位的地区中绿水足迹也低,表明在这些地区水足迹值取决于粮食产量。而在蓝水消耗量居前 10 位的省份中,有 3 个省份位于缺水的华北地区,分别是山东、河北和河南,各地区年平均绿水足迹曲线在这 3 个省份中出现了明显的拐点,表明其绿水足迹显著低于消耗同等数量蓝水足迹的地区; 这些地区中降水量少,并且地下水储量不丰富,之所以其绿水以及蓝水总量居于前列,其原因在于粮食产量大。因此在华北地区土地资源数量基本稳定的前提下,未来水资源数量将成为影响粮食生产的主要因素。

从区域角度看,华北地区是粮食主产区,该地区降水量少但是蓝水消耗量大,水足迹值高于其他区域。长三角和珠三角粮食作物的种植获益于丰沛的降水,因此,绿水足迹线到达这两个区域内的省份或者直辖市时会出现明显的波峰值,表明绿水足迹在总量中的比例相对其他区域较高; 但是该区域内的粮食种植相对于工业和服务业比重较低,因此其水足迹总量没有排在全国前列。西部部分省

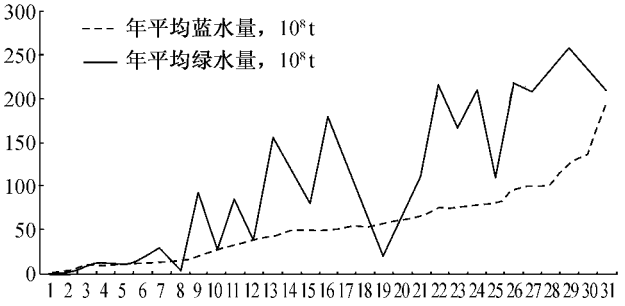

图 2 5 种粮食作物年度蓝水足迹总和年均值(1978 – 2010)

Fig. 2 Average total blue water footprint of five main food crops(1978 – 2010)

注: 1 西藏,2 青海,3 天津,4 上海,5 北京,6 海南,7 重庆,8 宁夏,9 贵州,10 甘肃,11 福建,12 山西,13 广东,14 辽宁,15 陕西,16 广西,17 吉林,18 云南,19 新疆,20 内蒙古,21 浙江,22 江苏,23 山东,24 湖北,25 河北,26 四川,27 江西,28 安徽,29 湖南,30 黑龙江,31 河南

份降雨丰沛,绿水足迹值高,粮食生产量大,水足迹总量也大,例如四川、江西等; 而有些省份比如西藏、新疆土地生产率低,粮食种植量少,因此水足迹总量也不高。

4.2.2 *各种主要粮食作物的水足迹值*

在 1978 – 2010 年间 5 种粮食作物绿水和蓝水足迹值总量中,稻谷水足迹总量占比最高,为 48%; 小麦、玉米、大豆和高粱依次占比 22%,18%,11% 和 1%。

在此期间,中国 5 种粮食作物中每一种粮食单位产量的蓝水足迹平均值减少,水资源生产率提高。如图 3 所示,小麦蓝水足迹降幅最高,约 59%,其他 4 种粮食作物水足迹降幅约为 30%。单位产量的小麦绿水足迹同期下降; 稻谷、小麦、玉米、大豆和高粱的降幅分别为 41.90%,58.71%,48.17%,43.76% 和 50.91%。国内粮食单位产量的水足迹数量减少; 而图 1 所示的国内生产消耗的水足迹总量基本持平并且略微增长,2010 年比 1978 年增长了

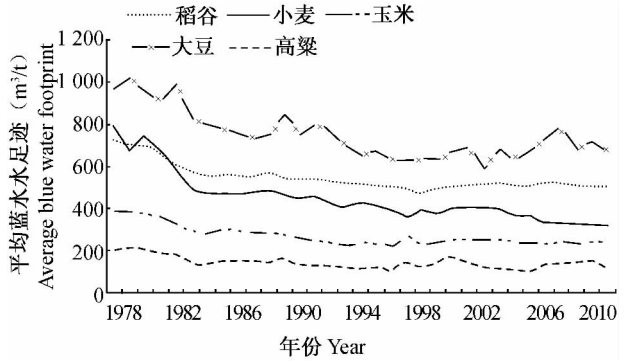

图 3 5 种粮食作物国内生产平均蓝水足迹(1978 – 2010)

Fig. 3 Average blue water footprint of five food crops' domestic production(1978 – 2010)

2.01%。其原因在于粮食产量的增加,在此期间 5 种粮食作物总产量从 1978 年的 2.54×10^8 t 增加到 2010 年的 5.06×10^8 t,增幅为 98.89%,几乎翻了 1 倍。粮食产量的增加抵消了水资源生产率提高对于减少水资源使用量的贡献。

4.3 国际贸易绿水和蓝水足迹比例

首先求出本年度粮食作物中进口绿水在中国消费绿水净值中的比例,同时求出蓝水的该比例; 然后将两个比值求比,可以得到国际贸易绿水和蓝水足迹比例。计算结果表明,绿水的比例在蓝水的 2 倍以上,即在粮食贸易中进口绿水占比高于蓝水。

图 4 显示,我国进口三大粮食产品稻谷、小麦和玉米绿水占比高于蓝水,并且该比例高于同类国内粮食产品的比值; 可以推测通过对外贸易,我国与其他国家将水资源重新分配,最终的贸易产品中各个国家出口了本国降雨而没有将本国宝贵的地下水资源同比例出口,因此在此过程中水资源以粮食为载体出口到了其他国家,水资源得到了优化配置。

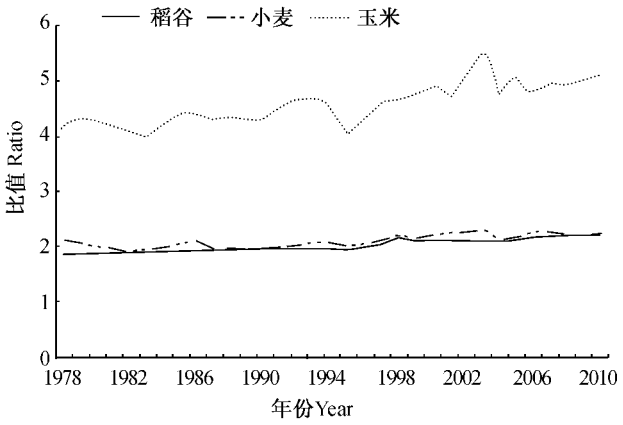

图 4 进口绿水与蓝水净值在总耗水量占比中的比值(1978 – 2010)

Fig. 4 Quotient of ratios between green and blue water footprint in total consumption(1978 – 2010)

4.4 水足迹与土地、人口和 GDP 的比值

4.4.1 *单位土地面积上的水足迹*

1978 – 2010 年 33 年间我国单位土地面积的粮食作物数量在增加,而单位粮食产量所需要的水足迹值在减少。以产量最高的稻谷为例,1978 年和 2010 年的稻谷单位面积产量和稻谷单位产量的水足迹值分别为 3 798.10 t/hm^2 和 2 064.37 m^3/hm^2,6 553.00 t/hm^2 和 1 288.61 m^3/hm^2。33 年间其水足迹值降低了 37.58%,单产提高了 72.53%; 两者散点图的斜率为负。

4.4.2 *人均水足迹值*

在此期间,我国人均消费的粮食作物绿水和蓝水足迹

先是缓慢下降,2003 年的人均数量最低,人均绿水、蓝水和水足迹总量分别为 256.83 m^3/人、121.27 m^3/人和 378.1 m^3/人,比 1978 年降低了 32.27%, 33.67% 和 32.72%; 人均蓝水足迹为绿水足迹的 47.21%。而从 2003 年起,我国人均水足迹值持续攀升,2010 年比 2003 年上升了 28.5%,达到 485.89 m^3/人,其中人均绿水足迹 340.45 m^3/人、人均蓝水足迹 145.44 m^3/人。2003 年之前的人均水足迹的减少原因与水资源生产率的提高关系密切; 而其后的人均水足迹的增加可以归因为粮食消费量的增速加快以及人口增长率的放缓。

4.4.3 单位 GDP 的水足迹

水足迹带来的经济效益,在这 33 年间持续增长; 单位 GDP 消耗的水足迹量持续下降,2010 年创造每一元钱的经济增长量,仅需要相当于 1978 年 1.09% 的水资源数量。这其中除了水资源利用效率的提升,还有一部分原因在于通胀的影响。以 1978 年为基准年,2010 年 CPI 上涨 174.9%,因此可以认为货币贬值使现在的每元钱的价值低于此前。尽管货币贬值速度约为 2 倍,而水足迹的价值提高了近百倍,因此单位水足迹产生的经济价值在提高。

5 结论与讨论

5.1 结论

对中国粮食作物水足迹进行系统性计算,对各个省份的水足迹研究结果表明,在蓝水消耗数量高的地区,绿水没有同步增加,反映了在部分缺水的粮食高产区如华北地区出现了大量抽取地下水灌溉粮食作物的情况。而绿水量较高的地区,蓝水数量没有攀升,说明在部分丰水的粮食产区如江南地区工业和服务业相对于农业更加发达,粮食种植数量较少。

1978 – 2003 年期间中国主要粮食作物水足迹消费总量基本维持不变、只在小范围内缓慢波动; 2003 年之后总量持续增长,并且进口量在总量中的占比 2003 年相对于 1978 年提高了 5.42 倍,加入 WTO 使我国对其他国家粮食产品以及水资源的依赖程度提高。从国内生产看,稻谷水足迹值在 5 种主要粮食作物中占 48%,它的单位产量的平均蓝水足迹在 1978 – 2010 年间降低了 41.90%。国内粮食生产平均水足迹值、人均水足迹值和单位 GDP 产出所需要的水足迹值均在降低,而水足迹总量增加,原因在于在此期间粮食总产量增加了 92.77%。而在进口的粮食作物中,绿水比例高于蓝水在水足迹总量中的比重,并且该比例高于我国国内粮食作物生产中的绿水和蓝水之比。通过国际贸易将富裕的绿水资源出口到了中国,优化了水资源配置。

5.2 进一步研究的方向

受数据可获性的影响,本文忽略了灰水足迹的计算; 而由省会代表该省的气象信息影响了计算结果的准确性,因此这些都是存在的可以改进之处。进一步量化计算土地资源、人口和经济等因素对水足迹的影响大小及作用机制是寻求降低中国粮食种植水足迹值的研究思路。

(编辑: 李 琪)

参考文献(References)

[1] Hokestra A Y, Chapagain A K, Aldaya M M, et al. The Water Footprint Assessment Manual: Setting the Global Standard [R]. Water Footprint Network, 2011.

[2] 诸大建,田园宏. 虚拟水和水足迹对比研究 [J]. 同济大学学报: 社会科学版,2012,23(4): 43 – 49. [Zhu Dajian, Tian Yuanhong. Comparision Research of Virtual Water and Water Footprint [J]. Journal of Tongji University: Social Science Edition, 2012, 23(4): 43 – 49.]

[3] Hoekstra A Y, et al. Virtual Water Trade: Proceedings of the International Expert Meeting on Virtual Water Trade, Delft [C]. The Netherlands, 12 – 13 December 2002, Value of Water Research Reports Series No. 12, UNESCO-IHE, Delft.

[4] Hoekstra A Y. Human Appropriation of Natural Capital: A Comparison of Ecological Footprint and Virtual Water Footprint Analysis [J]. Ecological Economics, 2009, 68: 1963 – 1974.

[5] FAO: AQUACROP 3.1 [DB/OL]. www.fao.org/nr/water/aquacrop.html, 2010b.

[6] Liu J G, Jimmy R W, Alexander J B Z, et al. GEPIC-Modelling Wheat Yield and Crop Water Productivity with High Resolution on a Global Scale [J]. Agricultural Systems, 2007, 94(4): 478 – 493.

[7] Siebert S, Döll P. Quantifying Blue and Green Virtual Water Contents in Global Crop Production as well as Potential Production Losses without Irrigation [R]. Journal of Hydrology, 2010.

[8] Mekonnen M M, Hoekstra A Y. A Global and High Resolution Assessment of the Green, Blue and Grey Water Footprint of Wheat [J]. Hydrology and Earth System Sciences, 2010, 14: 1259 – 1270.

[9] Sander J Z, Wim G M B, Cang F, et al. A Global Bench Mark Map of Water Productivity for Rain-fed and Irrigated Wheat [J]. Agricultural Water Management, 2010, 97(10): 1617 – 1627.

[10] Feng K, Hubacek K, Minx J, et al. Spatially Explicit Analysis of Water Footprint in the UK [J]. Water, 2011, 3(1): 47 – 63.

[11] Shilp V, Doeke A K, Zag P, et al. Going against the Flow: A Critical Analysis of Inter-State Virtual Water Trade in the Context of India's National River Linking Program [J]. Physics and Chemistry of the Earth, 2009, 34(4 – 5): 261 – 269.

[12] Buksink F, Hoekstra A Y, Booij M J. The Water Footprint of Indonesian Provinces Related to the Consumption of Crop Products [J]. Hydrology and Earth System Sciences, 2010, 16(8): 2771 – 2781.

[13] Chapagain A K, Hoekstra A Y. The Green, Blue and Grey Water Footprint of Rice from Both a Production and Consumption Perspective [J]. Value of Water Research Report Series, 2010, 70: 749 – 758.

[14] Mekonnen M M, Hoekstra A Y. Mitigating the Water Footprint of Export Cut Flowers from the Lake Naivasha Basin [J]. Value of Water Research Report Series, 2012, 26: 3725 – 3742.

[15] Ercin A E, Aldaya M M, Hoekstra A Y. A Pilot in Corporate Water Footprint Accounting and Impact Assessment: The Water Footprint of a Sugar-Containing Carbonated Beverage [R]. Value of Water Research Report Series, 2009.

[16] Jenerette G D, Wu W L, Goldsmith S, et al. Marussicha and W. John Roach: Contrasting Water Footprints of Cities in China and the United States [J]. Ecological Economics, 2006, 57(3): 346 – 358.

[17] 马静,汪党献,来海亮,等. 中国区域水足迹的估算 [J]. 资源科学,2005,27(5):96 – 100. [Ma Jing, Wang Dangxian, Lai Hailiang, et al. Water Footprint – An Application in Water Resources Research [J]. Resources Science, 2005, 27(5): 96 – 100.]

[18] Zeitoun M, Allan J A, Mohieldeen Y. Virtual Water 'Flows' of the Nile Basin, 1998 – 2004: A First Approximation and Implication for Water Security [J]. Global Environmental Change, 2010, 20(2): 229 – 242.

[19] 黄晶,宋振伟,陈阜. 北京市水足迹及农业用水结构变化特征 [J]. 生态学报,2010,30(23):6546 – 6554. [Huang Jing, Song Zhenwei, Chen Fu. Characteristics of Water Footprint and Agricultural Water Structure in Beijing [J]. Acta Ecological Sinica, 2010, 30(23): 6546 – 6554.]

[20] 何浩,黄晶,淮贺举. 湖南省水稻水足迹计算及其变化特征分析 [J]. 中国农学通报,2010,26(14):294 – 298. [He Hao, Huang Jing, He Huaiju. The Water Footprint and Its Temporal Change Characteristics of Rice in Hunan [J]. Chinese Agricultural Science Bulletin, 2010, 26(14): 294 – 298.]

[21] Allen R G, Smith M, Pette A. An Update for the Calculation of Reference Evapotranspiration [J]. ICID Bulletin, 1994, 43(2): 35 – 92.

Water Footprint Calculation of China's Main Food Crops: 1978 – 2010

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Abstract Water footprint is a tool that can evaluate the improvement in water efficiency. Increasing water scarcity in China's agricultural industry makes the quantification of water footprint important at different levels, from a crop to the nation. Based on Penman equation which illustrates the calculation method of green and blue water footprint per crop, this paper introduces water footprint calculation methods for a province, domestic production, international trading and domestic consumption. It calculates five main food crops: rice, wheat, grain, soybeans and sorghum's water footprints listed above in the year 1978 to 2010. The result shows that in the duration of the 33 years, rice production consumes 48% of the total water footprint, which is the largest of all the food crops. Comparing with green water footprint, the scarcer blue water's efficiency rises 40%. The total water footprint of China increases 2.01% by 2010 comparing with 1978. China is a net import country for those five main crops' water footprint. The percentage of imported crops' water footprint among the total consumption rises from 1.67% in 1978 to 9.06% in 2010, which means the increasing reliance of China on aboard water resource. Among imported water footprint, the quantity of green water footprint is 14.06 times of blue water footprint, which is higher than China's ratio of 1.96. It proves that through international trade, related countries exported their comparatively more abundant rain water to China, which relives China's water scarcity and makes international water usage more efficient. Finally, by comparing water footprint with land, population and economic development, it finds that in the past 33 years, the ratio of water footprint used per unit area decreased by 37.58%, water footprint per person decreased by 13.54%, and water footprint's economic productivity increased by 9.89%. The reason that total water footprint does not decrease while the comprehensive water footprint efficiency increases is the production of five crops increased by 98.89% during the period. The result can be used to evaluate further relationships between water footprint and other resources, population the economy.

Key words water footprint; agricultural industry; food crops; Penman estimation; CropWat

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【城市与可持续发展】

虚拟水与水足迹对比研究

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摘 要：虚拟水与水足迹将水资源研究从环境范畴拓展到了社会经济领域，是有效的水资源管理工具，但是两者既有联系又有区别。因此采用对比研究的方法，对虚拟水和水足迹的研究范围、研究对象、研究视角、计算方法和研究意义进行对比。结果发现在作物生长和气候条件已知的条件下计算农产品生产消耗的水量，虚拟水比水足迹更简便；与虚拟水相比水足迹应用范围更广。对于虚拟水和水足迹的辨析，有利于正确运用两种工具进行深化研究，以方便其在水资源利用中的应用。

关键词：虚拟水；水足迹；对比研究
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虚拟水和水足迹之前的水资源研究着眼于进行给水排水的技术改进或采用价格杠杆提高用水效率，却无力应对因水稀缺与水污染带来的水资源危机。虚拟水和水足迹从社会经济角度度量人类活动对于水资源系统影响，将水资源研究从环境领域拓展至社会经济领域；它们能够运用经济学与管理学工具从战略角度探讨水资源利用，对于应对水资源危机具有现实意义。1997年虚拟水概念提出，五年后水足迹概念提出并在虚拟水研究的基础上重点着眼于生产与消费过程中消耗的水资源与产生的污染量进行研究。两者有联系，但是也存在诸多不同，[①②]本文深入探讨了虚拟水与水足迹研究的联系与区别，以便于更好地运用这两种工具进行水资源研究。首先，回顾了虚拟水和水足迹的研究脉络；然后从研究对象、计算方法、研究角度、研究范围和研究意义等方面对两者进行了详细比较；最后述评并展望了虚拟水和水足迹深化研究的方向。

一、引 言

中东与北非地区是世界上第一个耗尽了水资源的地区，[③]为了应对这一地区的水资源危机，学者们积极探索各种解决方法。在1997年之前，水资源研究侧重进行技术改进和水价调控提高用水效率以应对水资源稀缺，但实践效果不明显；而自1997年Allan提出虚拟水概念和2002年Hokestra等专家提出水足迹概念后，学界将研究从环境领域拓展到了社会经济领域，深入研究生产与消费过程中消耗的水资源与产生的污染量，实践应用效果显著。

具体来讲，1997年Allan[④]提出“虚拟水”概念，即某种产品在生产时的用水量。它站在战略高度研究

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① Hoekstra, A. Y., Chapagain, A. K. *Globalization of Water: Sharing the Planet's Water Resources*. Blackwell Publishing, 2008.

② Bradley G. Ridoutt, Stephan Phister. A Revised Approach to Water Footprint to Make Transparent the Impacts of Consumption and Production on Global Fresh Water Scarcity. *Global Environmental Change*, 2010, vol 20, pp. 113-120.

③ Allan, J. A. *Water in the Arab World: Perspectives and Prognoses*. Harvard University Press, 1994, pp. 65-100.

④ Allan, J. A. Virtual Water: A Long Term Solution for Water Short Middle Eastern Economics? Paper Presented at The 1997 British Association Festival of Science, 1997.

农产品和畜牧产品贸易的水资源管理,其提出之初的目的是引导中东与北非地区政府制定有效的水资源政策,以解决中东与北非地区的水资源匮乏。[①] 虚拟水从生产者角度研究用水,是一维的水资源研究指标。

2002年在世界水贸易专家会议上Hokestra首次提及"水足迹"概念,[②]它指从个人、家庭、部门、某行业、城市到整个国家在生产或者消费的产品中包含的虚拟水数量。[③] 水足迹可以计算生产中或消费的水的种类(蓝水、绿水和灰水),以及何时何地产生了这些水足迹。水足迹从生产者和消费者角度研究用水,是多维的水资源研究指标。水足迹打破了将水资源管理局限在某地区或者流域内的局限,人们开始将全球水资源一起作为研究对象;寻求人类消费、全球贸易与水资源利用之间的关系。

此前的研究表明虚拟水适用于农产品生产中的理论用水量研究,在农作物气候、湿度、作物生长条件等条件已知时可以计算虚拟水量;而水足迹建立在虚拟水的基础上并将研究范围进行了拓展,因此除此之外它还能够计算消费者消耗的水资源数量、产生的污水量。明确虚拟水和水足迹的异同是正确运用这两种指标进行水资源研究的前提。因此本文对虚拟水和水足迹的研究进行比较研究,阐述了两者的联系与区别,并在此基础上探讨了未来的虚拟水和水足迹需要完善的领域。

二、虚拟水与水足迹的联系与区别

水足迹最初在关于虚拟水的国际论坛上被提出,由此可见水足迹沿袭了虚拟水研究。但是其后对两者分别展开的研究使两者有了区别,它们的研究范围、研究对象、计算方法、研究角度、研究意义均存在不同,如表1所示。

表1 虚拟水与水足迹研究比较

比较内容	虚拟水	水足迹
研究范围	参与交易商品中的理论用水量	从个人、家庭、部门、某行业、城市到整个国家在生产以及所消费的产品中包含的水资源数量
研究对象	蓝水、绿水	蓝水、绿水、灰水
计算方法	全生命周期法	全生命周期法;环境投入产出法
研究角度	生产过程中消耗的虚拟水	生产过程中或者消费过程中产生的水足迹
研究意义	改变生产者行为,缓解水资源短缺,实现供水和粮食安全,促进产业结构调整	改变生产者行为或者改变消费者行为,提高用水效率

1. 研究脉络

虚拟水是生产某产品的各个环节所消耗的水资源,"虚拟"既说明参与贸易的产品并非实体的水资源但需要由水资源生产,又表明在生产中消耗的水资源大多数并没有包含在产品中,因此虚拟水可以取代真实的水资源成为研究对象。虚拟水研究大致经历了三个阶段,第一阶段是虚拟水概念提出后至2000年,虚拟水研究意义的讨论;第二阶段是虚拟水计算方法的完善,以及世界各地虚拟水贸易量的计算;[④]第三阶段,虚拟水与国际贸易理论结合,研究国际贸易中的虚拟水的比较优势,为从战略高度管理

① Dennis Wichelns. The Role of 'Virtual Water' in Efforts to Achieve Food Security and Other National Goals, with an Example from Egypt. *Agricultural Water Management*, 2001, vol. 49, pp. 131-151.

② Hoekstra, A. Y. 2003. Virtual Water Trade: Proceedings of the International Expert Meeting on Virtual Water Trade, Delft, The Netherlands. *Value of Water Research Reports Series*, 2003, vol 12, pp. 12-13.

③ Hokestra, A. Y. and Chapagain, A. K. Water footprints of nations: water used by people as a function of their consumption patterns. *Water Resources Management*, 2007, vol 21, pp. 35-48.

④ A. Y. Hoekstra. Human Appropriation of Natural Capital: A Comparison of Ecological Footprint and Virtual Water Footprint Analysis. *Ecological Economics*, 2009, vol. 68, pp. 1963-1974.

水资源提供建议。在此期间,召开了数次虚拟水国际论坛进行专题讨论。2002 年第一次国际虚拟水专家会议回顾了该领域的发展,2003 年第三次世界水论坛讨论了虚拟水贸易与地缘政治学,2006 年第四次世界水论坛讨论了阿拉伯地区的虚拟水贸易。①

在水足迹十年的研究历史中,涉及了计算、影响因素分析、情景分析、水足迹对政策制定的影响等方面。这一期间召开的数次国际性的水资源论坛上对水足迹的讨论推动了水资源研究的开展。2002 年代夫特水资源专家会议上首次提出水足迹概念,随后 2003 年日本举行的第三届世界水论坛、2003 年世界水环境署召开的主题为"虚拟水贸易与政治地理学"会议、2005 年德国发展研究院召开的虚拟水贸易专家会议、2006 年第四届水资源论坛、2006 年在波恩由世界水资源系统项目举办的主题为"全球水资源政府治理"会议和在法兰克福由社会经济研究所举行的"虚拟水贸易"等会议上都对水足迹展开了讨论。

与其他用水指标相比水足迹有三个不同点:第一,可以度量整个产品生产或者服务提供过程中的直接与间接水资源消耗;第二,可以将某地区水资源消耗与全球水资源配置联系起来;第三,除去度量蓝水和绿水使用外,还可以度量灰水足迹,量化了产生的污染数量。其独特性使水足迹在三次产业尤其是农业中应用广泛,对于农产品贸易以及农产品种植的指导作用明显。

2. 研究范围

虚拟水研究参与农产品交易商品中的理论用水量。如 Hoekstra 和 Hung 计算出了不同国家生产不同种类农作物所需虚拟水量。Naota 等依据 ICOLD 提供的世界范围内的水坝供水量,将蓝水进一步细分为河水、中等水坝水、非再生以及非过境水三种,然后利用运用物理、水文和人类学原理建立的 H08 模型计算出了 2000 年全球五种农作物和三种畜产品的虚拟水交易量。② Mark 和 Allan 计算了 1998 年到 2004 年间尼罗河流域各个国家间农产品的虚拟水贸易,为保障尼罗河水资源供应安全提供参考。③

水足迹则试图通过研究从个人、家庭、部门、某行业、城市到整个国家生产或者消费的产品中包含的虚拟水数量,揭示生产或者消费方式和国际贸易与水资源管理之间的关系。Hokestra 等估算了 1997-2001 年间的全球生产过程中产生的水足迹。Hubacek 等运用投入产出法计算了中国 1997 年产生的水足迹。Feng 等对投入产出法进行了改进,采用多地区投入产出法计算了英国不同地区各消费阶层的水足迹。④⑤

3. 研究对象

虚拟水计算蓝水与绿水足迹,水足迹除此之外还增加了灰水计算,可以度量生产或消费过程中产生的污染量,是更加完善的用水指标。⑥ 灰水是生产某产品产生的污水数量,或者稀释生产或者消费过程中的污染物至某一标准需要的最大水量,控制产生灰水量最大的污染物数量产出能明显减少灰水足

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① 王克强、刘红梅、刘静:《虚拟水研究文献综述》,《软科学》,2007 年第 6 期,第 11-14 页。

② Naota Hanasaki, Toshiyuki Inuzuka, Shinjiro Kanae and Taikan Oki. An Estimation of Global Water Flow and Sources of Water Withdrawal for Major Crops and Livestock Products Using a Global Hydrological Model. *Journal of Hydrology*, 2010, vol 384, pp. 232-244.

③ Mark Zeitoun, J. A. Allan and Yasir Mohieldeen. Virtual Water 'Flows' of the Nile Basin, 1998-2004: A First Approximation and Implication for Water Security. *Global Environmental Change*, 2010, vol 20, pp. 229-242.

④ Feng, K.; Hubacek, K., Minx, J.; Siu, Y. L; Chapagain, A, Yu, Y.; Guan, D and Barrett, J: Spatially explicit analysis of water footprint in the UK. *Water*, 2011, vol 3, pp. 47-63.

⑤ Klaus Hubacek, Dabo Guan, John Barrett, et al. Environmental Implications of Urbanization and Lifestyle Change in China: Ecological and Water Footprints. *Journal of Cleaner Production*, 2009, vol 17, pp. 1241-1248.

⑥ A. Ertug Ercin, Maite Martinez Aldaya et al. Corporate Water Footprint Accounting and Impact Assessment: the Case of the Water Footprint of A Sugar-Containing Carbonated Beverage. *Water Resource Management*, 2011, vol 25, pp. 721-741.

迹,所以灰水足迹可作为进行技术改进、减少污染量的依据。[①] 灰水计算比蓝水和绿水计算复杂,需要不同地区的数据。Dabrowski 等[②]、Ercin 等、[③]Gerbens 和 Hokestra、[④]Van 等、Aldaya[⑤] 和 Hokestra、Bulsink 等[⑥]对多种产品的灰水足迹进行了计算。

4. 计算方法

虚拟水计算采取自下而上方法;水足迹还可以采用自上而下法计算。自下而上的方法是将生产某种商品或者服务从最初环节到最终环节所消耗的水资源加总;自上而下的方法是将一国用水总量加上该国虚拟水进口量减去虚拟水出口量。全生命周期法是一种自下而上计算方法,环境投入产出法是一种自上而下计算方法。[⑦] 两种方法相比各有利弊,以水足迹计算为例,以自下而上法除了可以计算国家水足迹外,还应用于个人、社区、城市等消耗的水足迹,计算范围广泛,但是需要具体到各计算环节的数据,计算量大并且容易在中间环节产生误差。自上而下方法计算水足迹更常用,它具有如下优点:第一,从投入产出的角度考虑,能够完全反映在整个过程中的水资源消耗,并且都是最终消费的水资源,既能够避免中间多个环节进行运算产生的误差,又能够减少表面耗水而非最终耗水的影响,适用于消费中的直接与间接水足迹;第二,多地区水足迹值的计算可以为产品国际贸易的优化提供依据。

Chapagain 和 Hoekstra 最先提出了虚拟水的计算方法,计算了不同国家农产品和畜产品中的虚拟水量;其研究团队还完善了水足迹的计算方法。[⑧] 对于计算所需数据,联合国粮农组织 FAO 提供各个流域的年降水量、径流量、土壤水消耗量、地下水量和国家每年种植各种农作物的单位标准耗水量;[⑨]ICOLD 提供世界范围内各个水坝年供水量;国家农牧业部门提供耕地量和农作物年产量;国家统计局提供不同农作物的需水量;国家进出口贸易局提供各种参与虚拟水贸易产品数量数据。[⑩]

5. 研究角度

虚拟水从生产者角度研究从产品生产之初到产品成型所消耗的水量,在不同国家或地区生产某种

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① Chapagain, A,K. ,Hoekstra,A. Y. ,Savenije,H. H. G. and Gautam,R. The Water Footprint of Worldwide Cotton Consumption of Cotton Products on the Water Resources in the Cotton Producing Countries. *Ecological Economics*, 2006,vol 60,pp. 186-203.

② J. M. Dabrowski,K. Murray,P. J. Ashton,et al. Agricultural Impacts on Water Quality and Implication for Virtual Water Trading Decision. *Ecological Economics*,2009,vol 68,pp. 1074-1082.

③ A. Ertug Ercin,Maite Martinez Aldaya et al. Corporate Water Footprint Accounting and Impact Assessment: the Case of the Water Footprint of A Sugar-Containing Carbonated Beverage. *Water Resource Management*,2011,vol 25, pp. 721-741.

④ Winnie Gerbens-Leenes,Arjen Y. Hoekstra. The water footprint of biofuel-based transport. *Energy & Environmental Science*,2011,vol 4,pp. 2658-2668.

⑤ Van Oel,P. R. ,Mekonnen M. M. and Hoekstra,A. Y. The external water footprint of the Netherlands: Geographically-explicit quantification and impact assessment. *Ecological Economics*,2009,vol 69,pp. 82-92.

⑥ M. M. Aldaya,J. A. Allan and A. Y. Hoekstra. Strategic Importance of Green Water in International Crop Trade. *Ecological Economics*,2010,vol 69,pp. 887-894.

⑦ Hubacek, K. and Sun L. Economic and Societal Changes in China and Their Effects on Water Use: a Scenario Analysis. *Journal of Industrial Ecology*,2005,vol 9,pp. 1-2.

⑧ Chapagain,A. K. and Hoekstra,A. Y. Virtual Water Trade: A Quantification of Virtual Water Flows Between Nations in Relation to International Trade of Livestock and Livestock Products,Virtual Water Trade. *Proceedings of The International Expert Meeting on Virtual Water Trade*,*Value of Water Research Reports*,2003,vol 12.

⑨ Hoekstra,A. Y. ,Hung,P. Q. Globalization of Water: International Virtual Water Flows in Relation to Crop Trade. *Global Environmental Change*,2005,vol 15,pp. 45-56.

⑩ Esther Velazquez. Water Trade in Andalusia, Virtual Water: an Alternative Way to Management Water Use. *Ecological Economics*,2007,vol 63,pp. 201-208.

商品所消耗的虚拟水量不同,因此国家或地区间的虚拟水贸易可以缓解因地区间水资源分布不均或者水资源生产率不同而造成的水资源短缺或者水资源使用低效率、解决因此而引发的地区冲突,实现水资源和粮食供应安全。

水足迹在虚拟水研究的基础上,将研究角度拓展到了消费者。不同地区消费理念与消费方式的差异也是影响水足迹值的原因之一。Feng 等研究了英国不同地区内居民的收入水平与水足迹的关系,发现两者线性相关;因此水足迹值能够反映不同地区的用水和污水量、具有地理指标的功能,可以在小范围内改进水资源消费模式以减少水足迹。

6. 研究意义

对于虚拟水研究的意义,目前学界并没有达成一致意见。支持者认为虚拟水能够缓解水资源紧缺,实现供水安全和粮食安全。Dennis 运用比较优势理论研究了埃及虚拟水贸易对于实现供水安全的意义。反对者同样运用比较优势理论进行反驳,Erik 运用俄林模型证明虚拟水贸易并无上述作用。[①] Dinesh 对 131 个国家农产品虚拟水贸易量和该国耕地量、农业用水量等七个变量之间进行了回归分析,发现自变量和因变量之间并无线性关系,从实证角度质疑了虚拟水贸易的作用。[②] 有学者认为出现上述争议的原因是目前的虚拟水研究局限在少数国家之间,若研究范围扩大,其对于供水安全的意义将显现。也有学者认为,相比水资源禀赋,可耕地数量是影响虚拟水贸易、保障供水安全的更关键因素。

计算地区内或者地区间的虚拟水贸易量可为政策制定提供参考。Esther 计算了西班牙安大卢西亚的农产品虚拟水贸易量后,认为制定政策改变该地区内进出口农产品的种类、减少出口大量耗水产品转而进口耗水多的产品能够缓解当地的水稀缺。尽管大多数人认为相对于绿水来讲,蓝水对于虚拟水贸易意义更大,Aldaya 与 Allan 等人通过计算全球农产品虚拟水中的绿水贸易,发现绿水较少产生环境污染并且可再生性强,因此应该提高绿水使用效率,而计划经济的实施能够提高绿水使用效率。[③] Dabrowski 等计算了稀释南非五种作物种植过程中所产生的富营养物质需要的水,发现该数值大于种植农作物所耗费的水,并且所需水量受稀释水中的蓝水与绿水比例影响。[④] 由此可见制定用水政策调节农产品生产过程中的蓝水和绿水比例颇具意义。

除具备上述意义外,水足迹还可以调节地区水资源消费以优化全球水资源配置。首先,水资源最终由消费者消费,因此将消费者所消费产品的水足迹计算出来,横向比较世界范围内不同地区间为了提供某种产品或者服务产生的水足迹,可以鼓励该地区制定合理的产业政策生产耗水最少的产品。Erctn 等计算了世界不同国家饮料生产过程的水足迹值,包括生产饮料原材料、生产饮料工人的消耗、运输饮料过程,发现生产饮料的农产品水足迹值是影响最终水足迹值的重要原因,因此对世界各国而言减少原料生产过程中的水足迹值才是减少饮料水足迹的关键。其次,一地居民既消耗本地供水即内部水资源,也消耗外地供水即外部水资源。为了评价用水模式对内部和外部水资源的影响,Feng 等研究了英国不同地区内居民的收入水平与水足迹的关系,发现两者线性相关。这些研究为改善本地用水模式、提高全球水资源配置效率提供参考。

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① Erik Ansink. Refuting Two Claims about Virtual Water Trade. *Ecological Economics*, 2010, vol 69, pp. 2027-2032.

② M Dinesh Kumar, O. P. Singh. Virtual Water in Global Food and Water Policy Making: Is There a Need for Rethinking? *Water Resources*, 2005, vol 19, pp. 759-789.

③ M. M. Aldaya, J. A. Allan and A. Y. Hoekstra. Strategic Importance of Green Water in International Crop Trade. *Ecological Economics*, 2010, vol 69, pp. 887-894.

④ J. M. Dabrowski, K. Murray, P. J. Ashton, et al. Agricultural Impacts on Water Quality and Implication for Virtual Water Trading Decision. *Ecological Economics*, 2009, vol 68, pp. 1074-1082.

三、研究展望

水足迹相对于虚拟水研究存在改进,但是有学者也认为其研究存在不足。未来研究中需要在不同的研究条件下在虚拟水和水足迹中选择其一作为研究工具;其次研究要与资源生产率、消费者行为理论结合;在研究中将引入有效的管理学工具,使虚拟水和水足迹的研究成果能够在现实应用中发挥作用。

若夯实虚拟水与水足迹研究的理论基础,需要将影响虚拟水与水足迹的因素与其他因素结合,如考虑土地因素运用比较优势理论指导农产品虚拟水国际贸易。或者将虚拟水与水足迹作为一种工具,验证提高资源生产率的相关理论是否合理等。目前已有学者通过计算出虚拟水或者水足迹的值,验证"资源咒诅"理论是否存在,检验 IPAT 中的各个因素对于水资源利用的影响等。

虚拟水与水足迹是有用的水资源管理工具,它既可以计算全行业中的耗水数值,也可以衡量小到个人大到一个国家的用水数值,利用这些计算结果,可以分别从生产者和消费者角度出发考虑如何改进用水效率。但是当前其研究领域从研究行业、研究角度到研究方法一直都局限在一定范围内使其潜能未发挥出来。未来虚拟水与水足迹的研究将由重点侧重农业转向关注全行业、由着重于生产者角度转向消费者角度、由大量计算转变为详细的数据分析、运用计量工具同时借助于管理学工具。

首先,将研究行业从农业拓展至第二、三产业。农产品是工业与服务业的原材料,农产品的生产会受到工业与服务业产业政策的影响,所以尽管工业与服务业直接耗水量相对于农业少,但是它们的间接耗水量却包括了农业耗水。因此,研究这些行业的水足迹、制定高水资源生产率的产业政策同样有意义。如 Elena 等计算了西班牙采用生物燃料需要消耗的虚拟水,预测了该新能源产业的发展将对供水产生的影响。全行业研究使将使水资源配置更加合理。

其次,研究消费者水足迹。水资源的使用受两大因素的影响,生产者的产业布局、用水效率和消费者的消费方式。此前对于水足迹的研究延续了虚拟水研究,一般从生产者角度出发,阐述不同国家或者地区生产某种产品所耗费的水足迹值。由于所有的用水都可以归结为消费者的最终消费,因此研究不同的收入阶层、消费方式下消费者的水足迹,深入研究个人、家庭、社区等较小的单位才能更有效发挥作用,更加有效地指导用水。

第三,运用经济学和管理学知识。目前虚拟水与水足迹研究大部分是从农业、环境或者地理学角度出发,未来运用经济学知识如国际贸易理论,并将研究出来的成果运用管理学工具如水资源政策工具等进行解释,将促使研究成果从实践层面发挥作用。

四、结 论

虚拟水和水足迹这两种水资源研究工具将研究范畴从环境领域扩大到了社会经济领域。以其为工具,计算产品生产中消耗的蓝水和绿水数量之后,分析该数量变化的经济、人口、贸易、技术等原因并采取改进策略,能够有效提高水资源利用效率。因此它们在利用水资源、缓解地区与国家水资源紧张、保障供水安全与粮食安全中发挥了效用。

与虚拟水相比,水足迹研究的研究角度从生产者扩展到了消费者、研究对象从蓝水和绿水足迹扩展到了灰水足迹、研究范围从某种农产品扩展到了一国或者全球的工业积极服务业产品,这是两者的不同之处。

虚拟水适用于农产品生产中的理论用水量研究,在农作物气候、湿度、作物生长条件等条件已知时计算虚拟水数量比计算水足迹值方便,而在计算生产中的污染数量、消费者消费的水资源数量的时候,需要采用水足迹值。明确两种计算工具适用的场合是有效运用这两种工具的前提。

尽管水足迹计算在虚拟水基础上进行了扩展,其研究也存在不足。水足迹缺乏区分水资源可持续与不可持续的能力,并且其研究中多计算而较少经济学或者管理学分析,使研究成果无法指导政策分析与制定、研究成果无法投入现实应用。若改变这种状况,未来虚拟水与水足迹的研究领域将会由农业拓展至其他产业,会由关注中东、北非、欧洲等地区拓展至关注世界各国,研究方法也会在地理、环境资源的基础上加入经济学运算与管理学政策理论与方法。

Comparative Research of Virtual Water and Water Footprint

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Abstract: Virtual water and water footprint are useful water management tools, which bring water research from environmental region to social economic region. Although they share similar characters, they are also different from each other. So based on comparative research, the aspects of research scope, objects, angle of view, calculation method and research meaning of them are compared. And the result shows that virtual water is more convenient under specific conditions, while water footprint has wider usage compared with virtual water. The distinguishing of virtual water and water footprint is helpful for further study with both of them, as well as better usage in water resource research.

Key words: virtual water;　water footprint;　comparative research

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上海市能源消费影响因素研究
——基于 IPAT 方程与完全分解法分析

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摘要: 基于 IPAT 方程运用完全分解法对上海市 2000 – 2009 年间能源消费量进行了分析,探讨规模效应、技术效应和结构效应等影响能源消费的三大关键因素在能源消费量波动方面的影响。结果表明:过去十年中上海市经济规模扩张的影响超出了技术效应和结构效应,是能源消费增加的主要因素;规模扩张的反弹效应抵消了产业结构的调整和技术进步减少的能源消费;今后追求适度经济规模,加大产业调整力度是缓解上海市能源供应压力的关键。

关键词: IPAT 方程;完全分解法;能源消费
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近年来,中国能源消费量每年均在 10 亿万吨标准煤以上,2008 年中国能源消费总量折合 138553 万吨标准煤,能源的大量消费使中国在 2009 年取代美国成为能源第一大进口国,这意味着中国存在巨大的能源缺口,不断攀升的能源需求量与供应量的失衡不仅威胁中国能源安全,并且不利于经济发展。反观 2008 年上海消费量为 10002.97 万吨标准煤,占全国总消费量的 7.22%,且近年来上海每年能源消费增速均在 10% 左右。因此,分析影响上海市能源需要的因素对于缓解上海市能源供需矛盾将具有指导意义。

文章基本结构如下:第一部分对于影响能源消费量的因素进行文献回顾;第二部分介绍了 IPAT 方程与完全分解法;第三部分利用完全分解法对最近十年中影响上海市能源消费量的各个因素进行了实证分析;第四部分是结论和进一步讨论的方向。

文章的贡献在于:以往对于影响能源消费的因素计算过于复杂并且没有充足的理论依据,本文将 IPAT 公式引入能源消费预测与影响因素计算中,强化了对能源消费进行分析的理论依据;同时完全分解法的应用也填补了此前对于影响上海能源消费的因素研究的空白。

一、研究文献综述

首先,能源消费是影响碳排放的格兰杰原因[1-2],而二氧化碳的排放是引起全球气温变暖的主要因素,因此减少能源消耗可以减缓全球气温变暖。其次,能源缺口不仅产生对他国的能源依赖,而且国内经济发展极容易受波动的国际能源价格的影响。因此,能源安全与经济发展和环境保护息息相关[3]。

(一)能源生产率影响因素研究

对于影响中国能源消费量的因素,国内外学者做了大量研究,Guo 等运用结构方程对 1980 – 2004 年能源结构、技术、管理和能源强度与中国的能源消费量之间的关系进行了分析,研究结果显示技术变革和管理水平在提高能源强度使用中起决定作用,原油使用比率是提高能源强度的主要限制性因素[4]。董锋等运用灰色关联分析和协整检验法实证探讨了技术进步、产业结构和对外开放程度对中国能源消费量的影响,研究结果表明政府财政用于科学研究的支出和第三产业比对中国能源消费量起到负向作用,外贸依存度对中国能源消费量起到正向作用[5]。于珍等以制造业为研究对象,针对产业调整路径、幅度对能源消费强度的影响进行了实证分析,研究结果表明

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通过控制能耗比重大、单位能耗产出地的产业可以有效降低能源消费[6]。完全分解模型是对分解模型考虑残差之后的改进,最先应用在对20世纪70到90年代影响世界能源使用因素的分析中[7],随后该模型在研究影响各地能源使用影响因素中得到应用,孙欣和李柏松运用完全分解法分别对中国能源强度和滨海新区能源消费进行分析,得出了强度和经济规模效应在能源消费中所起的主导作用[8]。完全分解模型的应用为研究影响上海市能源使用效率的因素提供了启示。

(二)IPAT方程及其应用文献综述

与系统动力学相比,IPAT方程涵盖了影响环境效应的各个因素,但是方程简单,适合于定量计算。该方程1971年由Ehrlich. P和J. Holdren提出,此后被广发应用于对人与环境相互关系复杂性和多样性的定量测度中[9]。何强等运用IPAT方程框架研究了北京市人口、经济增长、技术水平和经济结构等因素对生态环境的作用机制,发现北京经济增长给环境带来的负向效应明显超过了技术进步带来的正向效应[10]。刘扬、陈劭锋运用IPAT方程对经济增长与碳排放间关系进行了理论分析,发现碳排放随经济增长的变化,依次遵循碳排放强度、人均碳排放和碳排放总量三个倒U型曲线高峰规律[11]。邱寿丰运用IPAT方程,结合情景分析法对中国2020年的能源需求量进行了预测[12]。上述做法为运用IPAT方程对上海市能源消耗进行分析提供了借鉴。

二、方法与数据来源

本文以上海市第一、第二、第三产业为研究样本,基于IPAT方程,运用完全分解法分析了2000-2009年各个产业规模、产业结构以及技术进步对能源消费量的影响。数据来源于历年《上海统计年鉴》、《上海市环境年鉴》。

(一)IPAT方程

本文对能源消费进行完全分解的理论依据是IPAT方程,该模型是对能源消费量、人口、人均GDP与人均能源消费量四者之间关系进行阐述的一个概念性框架,是一个被广泛认可的环境、人口、技术和经济关系模型[13]。其表达式如下所示:

$$I = P \times A \times T$$

式中I,P,A,T分别代表环境负荷、人口、人均GDP、单位GDP的环境负荷。具体到能源环境分析的能源消费,IPAT方程可以写成如下形式[14]:

能源消费量 = 人口 ×(GDP/人口) ×(能源消费/GDP)

(二)完全分解法

J. W. Sun提出的完全分解模型是在完全分解模型的基础上进行的改进,它将残差项按照"共同造成,平均分配"的原则分配到每一个影响因素中去,最终实现无残差的完全分解。本文依据IPAT公式,将残差平均分配到影响能源消费的各个因素包括人口数量、人均GDP和单位GDP带来的能源消费中。其中的人口数量和人均GDP可以整合为GDP总量一个变量,同时将第一产业、第二产业和第三产业分开考虑,使影响上海能源消费的模型成为三因素模型,这三个因素即产业结构、经济规模和技术进步,表达式如下:

$$It = \sum_i P_t \times \frac{G_t}{P_t} \times \frac{I_{it}}{G_{it}} \times \frac{G_{it}}{G_t} = \sum_i G_t \times \frac{I_{it}}{G_{it}} \times \frac{G_{it}}{G_t} \quad (1)$$

其中Q_t,T_{it},S_{it}分别代表t时期的各个产业的国民生产总值,能源生产率和该产业在国民总产值中的比重,这三种因素对能源消费的影响分别成为活动效应、强度效应和结构效应[7]。

在该模型中,因素Q_t,T_{it}和S_{it}对能源消费量I_t的影响表达式如下:

$$Q_{effect} = \triangle Q \sum_i t_I^0 S_i^0 + \frac{1}{2}\triangle Q \sum_i (T_i^0 \triangle S_i + S_i^0 \triangle T_i + \frac{1}{3}\triangle Q \sum_i T_i \triangle S_i) \quad (2)$$

$$T_{effect} = Q^0 \sum_i S_I^0 \triangle T_i + \frac{1}{2}\triangle T(S_i^0 \triangle Q + Q^0 \triangle S_i) + \frac{1}{3}\triangle Q \sum_i T_i \triangle S_i \quad (3)$$

$$S_{effect} = \triangle Q \sum_i T_I^0 \triangle S_i + \frac{1}{2}\triangle S_i(T_i^0 \triangle Q + Q^0 \triangle T_i) + \frac{1}{3}\triangle Q \sum_i T_i \triangle S_i \quad (4)$$

能源变化的总效应即经济规模Q_{effect}、技术进步T_{effect}和产业结构S_{effect}三种效应之和:

$$I_{effect} = Q_{effect} + T_{effect} + S_{effect} \quad (5)$$

三、上海市能源消费影响因素实证分析

2000-2009年间,上海市能源消费总量由5083.73万吨上升至9698.13万吨,年增幅为9.08%;在此期间上海市*GDP*总量由4771.17亿元增加到15046.45亿元,增幅为21.52%,即能源增加

幅度小于 *GDP* 增长速度。虽然如此，根据过去十年能源需求增幅预测上海市到 2020 年内能源消费量将增加到 25154. 45 万吨，是 2010 年的 2. 59 倍。这意味着上海将面临着巨大的能源供应压力。本文实证研究了活动效应、强度效应和结构效应对上海市能源消费量的影响，其目的在于找出经济规模、技术进步和产业结构哪个是影响上海市能源消费的关键因素，*GDP*、能源消费值的原始数据来源于《上海市统计年鉴》，研究结果见表 1。

表 1　上海市三次产业能源消费总效应值

Table 1　Total Effect of Shanghai's energy consumption in three industies

产业	各年份中规模、技术、结构总效应值								
	2001	2002	2003	2004	2005	2006	2007	2008	2009
第一产业	10. 47	－4. 71	2. 7	－3. 48	－12. 05	－3. 99	－8. 39	7. 31	－13. 94
第二产业	212. 76	226. 38	182. 04	325. 98	217. 43	492. 79	642. 93	456. 28	－92. 81
第三产业	328. 65	325. 51	446. 38	598. 01	590. 83	1290. 66	979. 85	677. 53	－304. 85

根据表 1，上海市 2001 －2009 历年能源消费规模、技术和结构效应值中，第一产业效应值占比最小、第三产业总效应值占比最大。这是因为: 第一，农业单位产出能耗较低以及农业在上海市产业比重较低; 第二，第三产业在上海国民生产总值中所占比重逐步提高。为了推进产业升级建设新型城市，上海市一直在推动第三产业的发展。从 2005 年起，第三产业在国民生产总值中所占比例达到了 50%，与发达国家服务业占比 70% 相比，上海市还有很大提升空间，因此控制第三产业能源消费将成为未来上海首先考虑的问题。

表 2　上海市三次产业能源消费因素分解

Table 2　Factors that Influence Shanghai's Energy Consumption

三次产业因素分解					
年份	规模效应	技术效应	结构效应	总效应	对能耗影响
2000 －2001	433. 80	－91. 72	－13. 44	328. 65	增加
2001 －2002	510. 09	－154. 34	－30. 24	325. 51	增加
2002 －2003	868. 27	－532. 78	110. 93	446. 38	增加
2003 －2004	1156. 03	－561. 13	3. 11	598. 01	增加
2004 －2005	918. 45	－279. 46	－48. 15	590. 83	增加
2005 －2006	1028. 04	289. 71	－27. 09	1290. 66	增加
2006 －2007	1475. 23	－327. 98	－167. 39	979. 85	增加
2007 －2008	1148. 12	－374. 53	－96. 07	677. 53	增加
2008 －2009	662. 14	－701. 33	－265. 66	－304. 85	减少

根据表 2，历年中规模效应值均为正值，这是因为上海市经济规模总量的增大拉动了能源消费，根据未来十年中人均 GDP 翻两番的目标和每年 1. 1% 的人口增速，未来上海市规模拉动能源消费的正效应将不会变。从技术效应来看，2005 －2006 年第二、三产业的技术效应均为正效应，除此之外，技术效应对上海市能源消费均起着负作用，技术进步减少了能源的耗费量。从结构效应来看，2002 －2003 年以及 2003 －2004 年结构效应推动了能源的消费，这是由于这两年中第二产业比重均在上升，第二产业规模的扩大增加的能源消费大于其他两个产业规模缩小所减少的能源消费; 但是在其他年份，结构效应值均为负值，这与第二产业比重降低是同步的，意味着第二产业比重降低在减少能源消费所起的作用上能够抵消掉第三产业比重提升所带来的能源消费增加量，进一步能够明确第二产业相对于第三产业高能耗较高。从总体上看，上海三次产业总效应除 2009 年外均为正值，即对能源消费均起正向推动作用。其中规模效应起着决定性作用，2009 年上海市能源消费的技术效应和结构效应的负效应值高于规模效应的正值，才使得该年中的总效应为

负值。这意味着虽然技术进步能够减少能源消费,但是由于规模扩张带来的反弹效应将抵消掉前者的成果。

四、结论与政策建议

回顾国内外学者对能源需求进行预测和影响能源消费的各种因素研究的基础上,进一步明确了规模效应、技术效应和结构效应是影响能源消费的三大关键因素。依据IPAT方程对上海市2020年能源消费量进行了情景分析;同时依据此模型对2000－2009年间上海市能源消费的三大影响因素进行完全分解,其目的在于找出影响上海市能源消费的关键因素。研究结果发现,未来10年上海市能源消费将面临巨大的能源需求。而过去10年间影响上海市能源消费的主要正效应是规模效应,主要负效应是技术效应,并且规模增长所带来的反弹效应将能源效率提高带来的技术效应和产业结构调整带来的负向结构效应抵消,致使上海市能源消费总效应为正。这意味着未来上海市只有努力克服反弹效应,严格控制规模效应才能解决未来上海市能源危机的出路。

首先,异于2000－2009年的十年间的其他年份,可以看出2008－2009年之间能源消耗数量下降明显,分析原因可以看出其时规模效应虽然为正,但是相对于其他年份数量减少;技术进步与产业结构调整带来的能效使用率提高速度明显,因此在未来发展阶段为了控制能源排放量,控制经济规模也是不容忽视的一个环节,这与上海经济增长从原来求快到现在求稳的趋势不谋而合。

其次,从历年数据上看技术进步在减少上海市能源效应总量上占比最高,因此能源替代以及新技术、新材料的开发仍是减少能耗的重要手段。未来上海市在新技术的开发与应用上仍需要持续加大投入。

最后,上海市服务业发展迅速使其能源消耗在能源总量中占比逐渐增加,未来上海市将继续加大服务业发展力度,以期缩小与发达国家占比70%之间的差距,因此服务业的能源消耗仍处在上升阶段,为了减少能源消耗数量,提高服务业能源效率将是需要解决的问题之一。

参考文献:

[1] Ugur Soytas, Ramazan Sari, Bradley T Ewing. Energy consumption, income, and carbon emissions in the United States [J]. Ecological Economics,2007,62:482－489.

[2] 谌伟,诸大建,白竹岚. 上海市工业碳排放总量与碳生产率关系的实证研究 [J]. 中国人口资源与环境,2006,20(9):24－29.

[3] John S. Duffield. Germany and energy security in the 2000s: Rise and fall of a policy issue [J]. Ecological Economics,2009,37:4284－4292.

[4] Guo Ju'e, Chai Jian, Xi Youmin. Analysis of Influences between the Energy Structure Change and Energy Intensity in China [J]. China Population, Resources and Environment,2008,18(4):38－43.

[5] 董锋,谭清美,周德群,等. 技术进步、产业结构和对外开放程度对中国能源消费量的影响—基于灰色关联分析－协整检验两步法的实证 [J]. 中国人口资源与环境,2010,20(6):22－27.

[6] 于珍,李保明,施祖鳞. 产业调整路径、幅度与能源消费 [J]. 中国人口资源与环境,2010,20(6):92－97.

[7] Sun J W. Change in energy consumption and energy intensity: a complete decomposition model [J]. Energy Economics,1998,20(1):85－100.

[8] 李柏松,朱祗熹,包景岭. 滨海新区能源消费驱动因素完全分解研究 [J]. 城市环境与城市生态,2009,22(6):28－34.

[9] 刘刚,沈镭. 能源环境研究的理论、方法及其主要进展 [J]. 地理科学进展,2009,25(6):33－41.

[10] 何强,吕光明. 基于IPAT方程的生态环境影响分析——以北京市为例 [J]. 中央财经大学学报,2008(12):83－88.

[11] 刘扬,陈劭锋. 基于IPAT方程的典型发达国家经济增长与碳排放关系研究 [J]. 生态经济,2009(11):218－221.

[12] 邱寿丰. 循环经济规划的生态效率方法及应用——以上海为例 [D]. 上海:同济大学,2006.

[13] Ehrlich P R, Ehrlich A H. Population, resources, environment: issues in human ecology [M]. San Francisco: Freeman,1970:371.

[14] 诸大建,朱远. 循环经济与自然资本稀缺条件下的中国发展 [J]. 毛泽东邓小平理论研究,2008(4):34－40.

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Researches on Several Problems of Embezzlement

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Abstract: Embezzlement is a new crime added in China's Criminal Law which was amended in 1997,different knowledge and controversies on understanding about object of crime,refuse to return and refuse to surrender in embezzlement exist in both theory circle and judicial practice,this article will do researches on those three aspects,so that the essence and traits of embezzlement can be grasped.

Keywords: embezzlement; in commendam; lost property; refuse to return、refuse to surrender

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Research on Shanghai's Energy Consumption Based on IPAT Equation and Complete Decomposition Method

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Abstract: This paper used completely decomposition method based on IPAT equation to analyze energy consumption of Shanghai from year 2000 to 2009. The result shows that in the past ten years, economy's expansion is the main factor to increase energy consumption in Shanghai, by which the rebound effect reduce the effect of energy consumption decrease caused by structure's adjustment and technology's advancement. Then proper economy scale and abundant structure adjustment is the key to release energy supplement pressure in Shanghai from now on.

Keywords: IPAT equation; complete decomposition method; energy consumption

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