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Research Article

Key elements for functioning gas hubs: A case study of East Asia

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Abstract

This paper clarifies various concepts relevant to gas trading hubs and presents an innovative framework with key elements to create gas hubs. The nine key elements in the framework are further divided into basic elements for balancing hubs and advanced elements for benchmark hubs. The framework is applied to three East Asian case studies. The East Asian comparative case study shows that while Singapore is leading the way in establishing an LNG hub in Asia, the LNG hub concept is yet to be tested. Meanwhile, although China has the potential to host a gas hub, its current level of hub development is low. The paper suggests that these countries can advance their hub initiatives by strengthening the key elements as detailed in the proposed framework and create a more conducive environment through efforts such as market liberalization.

Keywords: Gas hub; LNG hub; Elements; China; Japan; Singapore

1. Introduction

Given the transition from oil indexation to hub indexation in Europe, the significant difference between East Asian spot and long-term LNG prices, and the concern with the "Asian Premium" [1], oil indexed gas pricing has been facing challenges in East Asia [2,3]. With the upcoming expiration of long-term supply contracts, short-term contracts and spot trade will increase, thus encouraging new thoughts on the way natural gas is priced. As hubs are the foundation for the creation of reliable (benchmark) price indexes for gas and LNG trade as alternatives to oil prices [4], many East Asian countries are planning to create local gas or LNG hubs [5].

Although several studies have addressed hub development experience, they do not address the question of how to create a gas hub. To date, the Oxford Institute for Energy Studies (OIES) has published three reports on hub building measures. In the first report, Heather [6] explains how a traded market operates but devotes little attention to the hub itself. In the second, Heather [7] measures the liquidity of most European hubs and categorizes them accordingly. In the third, Heather [8] evaluates the structure and effectiveness of European gas hubs and assesses the development of gas trading in each country. In another study, Miriello and Polo [9] focus on how the liberalization process creates a demand for wholesale gas—the foundation for a hub—but they do not address the key factors underlying the creation of a hub. Shi [10] studies Europe's experience in developing gas hubs with implications for Asia but he focuses on institutional and structural aspects such as market liberalization, separation of transport, and market players.

Abbreviations: CQPGX, Chongqing Petroleum and Gas Exchanges; DES, delivered ex-ship; FOB, free-on-board; JOE, Japan OTC Exchange; MT, million tones; METI, Ministry of Trade and Industry (Japan); NBP, National Balancing Point; OTC, over-the-counter; PRAs, price reporting agencies; OIES, Oxford Institute for Energy Studies; SGTM, secondary gas trading market (Singapore); SHPGX, Shanghai Petroleum and Gas Exchange; SLInG, SXG LNG Index Group; TPA, third party access; TSO, transmission system operator; TTF, Title Transfer Facility; VTP, virtual trading point.

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Although studies of Asia's gas market and hub development have emerged in recent years [1,2,11,12], these studies examine general issues and do not explain how a hub in East Asia can be created. A study from the International Energy Agency (IEA) [11] focuses on creating a competitive wholesale market and identifies some features of an Asian gas trading hub. The IEA [12] study presents a framework for the enabling factors of natural gas trading hubs, including hands-off governance, independent transport, third party access (TPA), wholesale price deregulation, sufficient network capacity, and a sufficient number of market players, but does not cover hub development itself. Shi and Variam [2] estimate the impact of various hub pricing scenarios on the world gas market and suggest that hub indexation and destination flexibility are favorable for East Asia. In the context of China, Shi [13] discusses the creation of a gas hub there. The US Energy Information Administration (EIA) [5] clearly defines the availability of infrastructure, with multiple pipelines that converge and interconnect, as well as the presence of numerous trading parties, as the foundation for hubs.

However, no study has discussed the key elements for successful hubs. The present paper fills this gap by examining the central question: what are the elements needed to create a benchmark hub? The contribution of this paper is three-fold. First, it proposes a reference framework that includes the key elements for establishing a gas hub and discusses their applicability to an LNG hub; second, it clarifies various concepts on hubs; and third, it comparatively analyzes the gas or LNG hub development status in China, Japan, and Singapore using the reference framework.

The development of gas markets in key East Asian countries such as China, India, Japan, and South Korea will add complexity and dynamics to the regional and global gas/LNG markets, thus necessitating more studies. East Asian gas markets will become more important to gas producers and the global LNG trade due to the uncertainty of Europe's demand and the disappearance of North America as an LNG importer [12]. East Asia is expected to become the second largest gas consuming region by 2025, with 790 billion cubic meters (bcm) of natural gas demand [11], and an important market in the global context. Over 73% of the global LNG demand is from Asia and 61% of that is from China, Japan, Korea, and Chinese Taipei [14].

The paper proceeds as follows. Section 2 presents the definitions of terms and the methodology. A reference framework including key elements for functional gas hubs is then proposed in Section 3. Section 4 compares the hub development status in the three countries mentioned based on the framework. Section 5 concludes the paper.

2. Methodology

The creation of a gas trading hub and its development as a benchmark hub have a few key prerequisites. In order to reveal these key elements, we draw on international experience, mainly that of the US and Europe, in the development of gas hubs. Based on a literature survey, this paper proposes a reference framework of nine elements for creating hubs. The key elements of a hub are selected from various reports, including the "European Gas Hub Study" [15−17], which scores individual European hubs annually, as well as elements recommended and verified by the literature. For example, the IEA [11] reports that the major parties involved in the development of a natural gas hub include market participants, transmission system operators (TSOs), hub operators, brokers, and exchanges. The framework is then used to assess hub pricing initiatives in China, Japan, and Singapore.

2.1. Definition of hubs

Before discussing what is needed to create a hub, it is necessary to clarify the meaning of a hub, as the definition will affect the scope of the elements. Although gas hubs have been a hot topic, there is no clear definition that emerges from the various concepts of hubs. In other words, the concepts of hubs in the extant literature are diverse and sometimes contradictory. The hub concepts include varied terminologies such as hubs, benchmark hubs, financial hubs, balancing hubs, virtual hubs, physical hubs, risk management hubs, and exchanges. Such terminologies are sometimes contradictory. For example, Heather [8] stated that all European hubs were "balancing" hubs but only the most mature and successful hubs (i.e., the National Balancing Point (NBP) and Title Transfer Facility (TTF)) were "trading" hubs (in addition to being balancing hubs). In contrast, the IEA [11] labeled all European hubs as "trading hubs," regardless of their liquidity and the existence of financial trading. The European Federation of Energy Traders [17] seems to agree with the IEA [11] calling all European hubs, including the nascent ones, trading hubs. Thus, to date, a clear definition cannot be found within the extant literature on this topic.

This paper follows the IEA [11] approach by defining a hub as a platform where the title (ownership) of gas molecules is exchanged between a number of buyers and sellers in both spot and futures trades and by treating gas trading hub, hub, and trading point as interchangeable. The following subsections define some sets of hubs.

2.1.1. Physical hubs versus virtual hubs

A common hub classification is into physical delivery points and virtual market places. A physical hub is a geographical (centrally located and sufficiently interconnected) point in the network where a price is set for natural gas delivered at that specific location [11]. This mostly exists in North America with the Henry Hub as a typical example. The EIA [5] defines the presence of multiple converging and interconnecting pipelines, as well as numerous trading parties, as the foundation for such a hub.

In the case of a virtual hub, trading hubs can also be used interchangeably with virtual trading points (VTPs). VTPs are associated with the entry-exit system (market area) from which point the same or other network users can transport the gas to exit points [18]. A VTP is usually within a market

(balancing) area [19] and is, thus, identical to a virtual hub [11].[1] In European countries, the area of a virtual hub often overlaps national boundaries. For example, the NBP was established as a daily balancing tool for the entire British geographic area [11].

The differing structures of the markets, where transport activities are fully privatized in North America but regulated in Europe, are believed to underlie the two different approaches: hubs are used to facilitate trade in the US but are meant for daily balancing in Europe [20].

2.1.2. Balancing hubs versus financial hubs

"Balancing Hubs" are used by shippers to balance their portfolios that are near maturity and at delivery, and by the TSO to physically balance the gas grid, often on a daily basis[2] [5,8]. In a liberalized market, the country will have to establish at least a "balancing" hub in order for the TSO to balance the gas grid. A balancing hub could be a transit hub, which moves a substantial volume of gas but has little actual trading.

A financial hub offers futures contracts used by the shippers to optimize portfolios and manage longer term risk (for hedging or speculative purposes), often up to three years or more, in advance, or even by financial players to speculate [8]. Although all the trading hubs are essentially financial, as they would primarily trade futures contracts, only those hubs that have liquid futures trading can be termed as "financial hubs." Currently, only the British NBP, the Dutch TTF, and the US Henry Hub are financial hubs.

All trading hubs must be "balancing" hubs but only a few can be "financial" hubs. For example, while there are many balancing hubs in Europe, and many European hubs have futures products, only the NBP and TTF have liquidity and trading volumes of futures with longer maturities [8], and thus, only the NBP and TTF are benchmark hubs.

2.1.3. Benchmark hub

A benchmark hub is one that offers prices for other hubs, and thus, the number of benchmark hubs is very limited. A benchmark hub, or a price marker hub, must have good liquidity from spot to several years forward and be fully transparent, open, and accessible to a wide range of participants [8]. It is a risk management hub and is, therefore, a financial hub, but not all financial hubs are benchmark hubs.

Although every European Union (EU) member state will have its own physical gas hub, only a few of these hubs will likely emerge as benchmark hubs. For example, despite the possibility of trade along the forwards curve in the over-the-counter (OTC) market in each of the European gas hubs, only the NBP and TTF hubs trade in quantities beyond the month ahead contracts (and up to about three years forward [8]). In North America, while there are also many regional physical trading hubs reflecting local and regional supply and demand balances, natural gas in US hubs is frequently traded at a price differential from the Henry Hub [11].

2.2. Scope of hubs for this study

Considering the various definitions of "hubs," for this study, we define a trading hub in the broad sense of the concept. A hub, or a trading point, is the place where buyers and sellers exchange the ownership of gas on paper and in physical delivery.[3] The basic role of the hub is the transport of gas from suppliers to consumers as per the contracts at their time of maturity.

Gas in a hub has a single price, or there is no cost difference. In other words, gas can be transferred at zero cost within the hub. In one country, there could be many such kinds of zero-cost zones. A zero-cost zone could be as big as a national network, as in the case of the UK and the Netherlands, or as small as an interconnection point, as in the case of the Henry Hub.

Since the density of pipeline connections in the US is unparalleled, we focus our discussion on the virtual hub, which is more feasible and popular in Europe. Europe is more interested in building a virtual trading hub because the virtual hub has a more flexible trade arrangement and is open to more participants than a physical one [11]. The VTP does not correspond to any physical entry or exit point. Thus, this allows gas buyers and sellers to buy and sell gas without booking capacity, which, therefore, maximizes the number of market participants [19]. Since all the current hubs in East Asia are virtual hubs, most of our investigation will draw from the European cases.

3. Key elements for function gas hub: a framework

The key elements for a hub are selected from various studies including the "European Gas Hub Study" [15–17]. The elements adopted here and their details are presented in Table 1.

Administrative participants, such as the TSO/balancing agent and storage operators, are also key hub participants [8]. The main tasks of the hub operator are to operate a virtual trading point and ensure balancing of the system. The exchange facilitates the title transfer, while the hub operator manages the title transfer infrastructure [19]. Elements that are not adopted include operations of hubs (consultation mechanism, title transfer, cash out rules, credit arrangement, market structure, and regulatory jurisdiction) and results (reference price, reliable price index, and firmness of hub), which are not associated with the hub itself [17]. Other high-profile factors, such as third party access, retailing competition, and market liberalization, are not included in this framework, as they are enabling factors and not elements of the hub.

[1] The IEA only mentioned the VTP in the case of the NBP and treats the VTP as identical to the virtual hub.

[2] The usual reason for spot trading is to physically optimize or balance a portfolio at, or just ahead of, physical delivery.

[3] The ownership is exchanged either for risk management trades (i.e., financial trades) or delivered physically (physical trades) for consumption or balancing transactions.

Table 1
Key elements for gas hubs.

EFET hub elements	Our framework	
	Basic elements for all hubs	Additional elements for benchmark hubs
Entry–exit system established	A trading point; could be a virtual trading point or a physical network interconnection. The trading point is operated by the TSO.	In the case of a benchmark pricing hub, one trading point needs to be designated as the benchmark hub.
Defined role of hub operator	Provides some services in addition to the infrastructure under the trading point. Could be undertaken by TSOs or exchanges.	
Establishment of exchange	Trading platform, often an Exchange.	
Standardized contract	Specification of contract and products including but not limited to standardization.	Derivatives products and market to be developed
Price reporting agencies (PRAs)		PRA published assessment of traded prices and price indexes for various kinds of contracts.
Market makers, brokers, and access to non-physical traders	Right mix of market players including participation of financial players.	The number of players and the market liquidity have to be sufficient to allow for competition. Financial market participants.

Sources: EFET [17]; Authors' assessment from the literature.

LNG hub development complicates the assessment of the Asian cases more than traditional hub development. Although LNG hub development has become a hot topic in the LNG industry, such an LNG hub has not been established anywhere and the concept is not free of controversy. On the one hand, an LNG hub would facilitate price benchmarking by circumventing the need for a physical trading point in gas hubs. LNG is moved in cargo containers and its trade does not rely on a pipeline network transportation infrastructure. Storage requirements are fewer in an LNG hub than in a gas hub because LNG is transported in the storage format and all the LNG regasification terminals have corresponding storage facilities. This circumvention can hasten hub development, as no Asian country has the necessary infrastructure in interconnected pipelines. The current hub indexes, such as Argus ANEA, Platts JKM, and the SGX LNG Index Group (SLInG), do not have an underlying delivery infrastructure, and thus, can be developed at a regional level. On the other hand, an LNG hub will suffer from technical limits, such as larger and lumpier products, significant time between contracting and delivery, differing LNG cargo specifications, lack of interconnectivity and technical compatibility between LNG import terminals, different operating rules set by bilateral contracts, and no uniform governmental regulations [5]. For these reasons, the liquidity in LNG trading is limited, and thus, the current LNG hub price indexes are all based on assessment and not on actual trading prices.

This section explains the key elements shown in Table 1. Considering that a balancing hub and a benchmark hub are in different stages of development and thus have different elements, we categorize these into basic elements that are applicable to both types of hubs and advanced elements that are only applicable to benchmark hubs. Compared with a pure balancing hub, a benchmark hub offers prices for other hubs, and thus, will need to have a sufficient number of market players, a benchmark delivery point (often an entry/exit zone), and sufficiently liquid futures markets to discover the market fundamentals. Price reporting agencies (PRAs) are also likely needed to produce price indexes, as it is often the case that not all trades are conducted on the exchange.

3.1. Basic elements for balancing hubs

3.1.1. A defined trading point: network, TSO, and associated storage capacity

The basic element for a hub is the presence of a trading point for buyers and sellers to meet and agree to transaction. In a physical hub, the trading point is the interconnection of pipelines. In a virtual hub, the price in the market area, called the "entry-exit zone" (often the entire national network), is uniform in the entire balancing zone (defined as the trading point), without geographic differentials due to transport costs [20].

Whether it is physical or virtual, a trading point needs adequate physical pipeline capacity for gas ownership exchange between suppliers and end buyers, that is, adequate interconnection facilities as well as nearby gas storage [5]. Since gas molecules have to be transferred through pipelines and allow for daily balancing in each single entry/exit market area, sufficient network capacity is essential to a well-functioning natural gas market, and thus, a hub [11]. Both physical and virtual hubs are located in the gas transmission system where product transfer is logistically possible [18]. At a physical trading point, sufficient interconnection at one particular point is needed to allow gas to be transferred to the final consumers. In the case of virtual trading points, an adequate, often meshed, network is needed, which allows the gas to move freely in the entire market area without cost differences. Sufficient infrastructure will prevent constraints that distort prices within the market area. For example, "island" markets would behave according to the dynamics of their own supply/demand rather than the hub's fundamentals [8].

For the prices in one hub to be accepted by market players outside the hub area, inter-connectivity with other markets is also needed. The reason a particular hub is designated as a delivery point is that gas can be traded across networks as needed. For example, the Dutch TTF is acceptable in Germany because gas traded in the TTF hub can be delivered to Germany. In contrast, the inadequacies of the infrastructure capacity and interconnections within France resulted in a price de-linkage between PEG Nord and PEG Sud in 2012 and 2013 [8].

The success of a hub depends primarily on getting the physical aspects right including defining an entry/exit zone where there are non-discriminatory access rights and balancing services [21]. Many officials, including members of the Spanish government, have argued that too much attention has been paid to the financial aspects of a hub (i.e., the creation of a platform to trade on spot and forward contracts), and not on the physical aspects of the infrastructure [21].

The infrastructure is often managed by the TSOs. The autonomy of the TSOs from their parent companies or other suppliers is critical in the successful development of European gas hubs. Essential elements to guarantee sufficient and non-discriminatory network capacity are an independent TSO and a well-developed network code (set of rules), as demonstrated by the success of the NBP, ZEE, and TTF [11]. In contrast, the absence of a credible TSO that could ensure third party access resulted in the ultimate downfall of the German Bunde/Oude hub [11].

Each hub requires robust storage capacity in order to balance supply-demand swings. This is particularly relevant to the majority of the European countries that are increasingly relying on imports as their main source of supply. The storage can also avoid extreme price movement due to supply disruption and other short-time factors and sudden event.

3.1.2. Hub operator, often the TSO

Hub operators provide services such as registration of OTC trades and records of exchange-based trades, title transfer and matching services, trade firmness through back-up/-down, the operation of balancing the market, market surveillance, and reporting [16]. The role of a hub operator is largely assumed by the TSOs (the infrastructure operator), such as in Europe [11]. Occasionally, exchanges also assume the role of a hub operator (in the case of CEGH and NPG) [18].

The difference between a hub operator and a TSO is that the hub operator liaises with the market participants and undertakes administrative tasks, while the TSO operates the transfer of gas (dealing with the network system). Operators of hubs could also offer commodity exchange services, such as wheeling, park and loan, storage, title transfer, and trading [5]. Since the hub operator is not identical to the TSO, it should be defined.

3.1.3. A trading platform, often in the form of an exchange

Trading platforms provide places where the price of gas at various physical locations is revealed. The exchange is a specialized trading platform that trades the hub products, mainly futures products but also some spot products, with the gas hub as the delivery point [11]. A gas exchange allows parties to anonymously buy or sell gas since the exchange is the counterparty in all transactions.[4] The clearing-house appointed by an exchange provides financial guarantees to execute all of the trades [22]. An exchange plays a critical role in the development of a traded commodity market through five important functions: price discovery, price transparency, supply/pricing flexibility, physical balancing, and financial risk management [22,23].

Functioning or deregulated wholesale competition can provide a price signal for the spot and forward markets [24] through a gas exchange that can be built on the deregulated wholesale gas market [11]. A perceived benefit of exchange-based trading is that transactions take place on exchanges that facilitate transparent, centralized trade in standardized products [11].

Although exchanges tend to provide futures contracts, sometimes they are used for actual physical transactions as a small percentage of the traded contracts do go to delivery at maturity. For example, in the case of Europe, the volume of the trade of futures contracts concentrates almost entirely on the ICE/Endex that trades the NBP and TTF, while that of spot contracts is more evenly distributed among the ICE/Endex and EEX (merged with Powernext) (Heather, 2015).

An exchange is not identical to a hub. Specifically, an exchange is not exclusive to a hub and there can be multiple exchanges trading the same products from a hub. An exchange could trade futures from different hubs and one hub's futures could be traded on several exchanges. For example, the NBP contracts are traded on the New York Mercantile Exchange (NYMEX), ICE/ICE-Endex, and EEX, and the ICE-Endex trades contracts from the NBP, TTF, NCG, GASPOOL, ZEE, and ZTP [8].

In some cases, physical hub products are traded on different gas exchanges, while in others, their locations match [18]. For example, the ZEE is a physical hub and a gas exchange. In contrast, the Henry Hub is just a physical hub and not a gas exchange, as gas is traded on the NYMEX. The Henry Hub is designated by the NYMEX as the delivery point due to its centrality and sufficient interconnections that allow for convenient exchange of natural gas ownership.

3.1.4. Specification and even standardization of products (contracts)

While gas is technically homogenous and can be conveniently measured by heat content, it is still differentiated by time and geographic dimensions. The standardization of traded products/contracts by their place and time of delivery is key to creating a successful hub, through concentrating liquidity that attracts volume, which further attracts traders [8]. This is a simple yet necessary element to make gas a tradable commodity. With standardization, financial parties can value these commodities easily and start buying and selling these products, mainly derivatives on the futures market [11].

Spot contracts[5] (defined as contracts exercisable in all periods within the month, including the month ahead) are mostly

[4] Exchange participants submit offers to sell and bids to buy on the exchange (i.e., bid and ask). The exchange matches bids and asks, and establishes the market-clearing price. Trading in an exchange is anonymous. The exchange reports on its website the results of the trade, which include bid, ask, final price, and quantity.

[5] Heather (2010) classified the traded curve into the spot (today or tomorrow), the prompt (all other periods within the month), the near (front month to the first two seasons), the mid (about two years forward), and the far curves (up to about five years forward, and even possibly to 10 years in the NBP and TTF).

used for final portfolio optimization ahead of physical delivery and/or for balancing at maturity. In the case of the NBP, the uniform network code (UNC or Code) prescribes two forms of gas trading: 1) spot OTC for day-ahead transactions; and 2) the on-day commodity market (OCM) for deals to balance the market [5]. Most trading activities take place in the spot market. Products such as intra-day, day-ahead (gas for delivery next day), and month-ahead (gas for delivery next month) products are the most frequently traded products on the European exchanges [8].

3.1.5. The right mix of market participants

A genuine market for a liquid gas hub requires a number of parties with competitive market shares along a non-regulated value chain (upstream and downstream) [11]. Physical parties (shippers), namely, producers, wholesalers, retailers, and consumers, who use the spot market as a balancing tool [11] form the basic group of participants. The physical participants are often dependent on market liberalization initiatives such as unbundling and the opening of the gas business to the private sector.

The number of participants indicates not only the convenience of trading gas on the hub but also the level of competitiveness. In European gas markets, it is suggested that a minimum of 10 active companies (those who trade at least once per week) is necessary to form a functioning competitive market [8]. For example, ZEE has more than 50 financial market participants who operate under the management of APX Gas ZEE [25].

All market participants, including suppliers, consumers, and financial institutions, will have to be a member of the hub in order to trade gas. At the end of the day, the market participants need to "nominate"[6] gas contracts to the hub operator who can then change the ownership of the gas at the hub.

3.2. Advanced elements for benchmark hubs

The above hub elements are necessary but not sufficient for a successful liquid hub. A benchmark hub requires significant trading volume, particularly in futures contracts, as well as a reasonable churn rate, among others. The futures market is needed to discover prices to manage price risk as well as boost liquidity.

3.2.1. Designation of a benchmark hub

In a connected and competitive market, prices in different local zones or hubs will follow the "law of one price" (i.e., prices are only different in terms of the amount of transport cost). In this connected market, it is, thus, possible to set one hub price as the benchmark and net back the rest of the hub prices from this benchmark hub price. Such a benchmark hub is exclusive in so far that: once it is established, it will attract all the futures' liquidity and make it more difficult for another hub in the interconnected market to generate liquidity sufficient for another benchmark hub [10]. In contrast, without a benchmark trading hub, it will be difficult to have a benchmark price index because it is challenging, and to a certain extent impossible, for the aggregation of the different zone prices to generate an index.

As shown in the case of the Henry Hub, a trading hub often needs a central location and sufficient connecting points for the exchange of gas ownership (IEA, 2013). However, the NBP is another example where a virtual hub with a uniform price within the hub is a possibility. The British VTP, the NBP, was the first virtual hub established in Europe (in October 1994) and was chosen by the Intercontinental Exchange (ICE) as the pricing and delivery point for its natural gas futures contracts [20].

The larger the benchmark zone is, the more liquidity there can be in the spot market. However, the boundaries of a benchmark hub are limited by the underlying pipeline infrastructure, which will have to allow gas to be transferred to anywhere within the hub without a cost difference.

3.2.2. Development of derivative markets

In the futures market, natural gas has become an energy derivative, and a "financial" transaction does not necessarily involve the physical exchange of natural gas [11]. Most "financial players" will trade futures rather than spot contracts [22]. With the growing numbers of varied participants in a particular market, a longer-term forward curve will develop, which can be used to manage risk. The robustly traded forward price is the final stage in the evolution of a benchmark gas hub [5]. Futures trading will be concentrated in benchmark hubs. Development of a liquid futures market is not feasible for non-benchmark hubs.

While spot prices play a foundation role, the benchmark gas prices are mainly based on futures prices. The development of futures markets is a natural evolution of market development. Wholesale trade is initially developed to cope with the balancing needs when the shipper and supplier segments become more fragmented [9]. At this initial stage, the gas traded at the hub is for the purpose of supply or consumption. Once the market becomes more liquid, it can be a second source of gas procurement, offering an alternative to long-term contracts [9]. Since gas has become an independent commodity, risks from its price variability will have to be managed by financial instruments in its markets [9]. Finally, to manage price risk, financial instruments are traded [9]. Futures products provide low-cost, standardized price risk management for gas deliveries [5].

A link between physical natural gas markets and financial institutions is needed to reduce counterparty risk, and provide a clear, long-term price signal [11]. On the one hand, for the futures markets to work, traders need a widely traded physical market from which prices for futures contracts can be derived. Only after long-term physical trading will market participants have confidence in the markets, and then, futures can be developed based on such spot markets. Exchanges will only offer futures contracts for a given commodity when there is an

[6] Nomination is an electronic message stating the volume of gas transferred, the period, the gas quality, and the buying and selling parties.

established underlying physical market because the futures contracts are "derivatives" of the physical futures contracts [8]. On the other hand, physical settlement is crucial when financial settlement is out of the question. Exchanges offer alternative platforms for executing physical trades through cash settlement [5]. However, even if cash settles the trade, a physical market still has to be selected, to determine prices for settling the deals. In commodity markets, there is no success for futures without spot markets. In the case of the separation between futures and spot markets, futures markets need clearing houses to avoid systematic risks.

Once the futures market is established, liquidity in the spot market is necessary but not sufficient, as the futures market will set the benchmark prices. The "churn rate"—"the multiple of traded volume to actual physical throughput"—is an important indicator of liquidity. The rate measures the number of times a "parcel" of gas is traded between its initial sale by the producer and the final receipt by the consumer [8]. This indicator is more frequently used than other indicators such as number of market participants. It is reported that Gazprom requires a minimum "churn−rate" of 15 to deem a hub as credible (liquid) [10].

3.2.3. Financial market participants

Financial participants (banks and hedge funds/proprietary traders) are critical in developing a functional hub. Financial institutions are willing to take risk to create profit. They can increase competition in the market by bearing the price risk of gas for future delivery and trading an increasing number of products involving future delivery [11,20]. The creation of futures products will increase access to the market, especially for non-physical players [8] who are the drivers of the high churn rate. Financial parties often use the OTC or exchange products to hedge and manage risk and speculate. The proportion of financial players is an indicator of the maturity and a measure of confidence in that market [8]. Openness and transparency are key factors in attracting financial players for better liquidity. Financial participants also prefer a virtual hub.

The physical and financial parties are interdependent. Although financial parties are present mostly in the futures market, they sometimes depend on the spot market to unwind their positions. As financial parties are usually not involved in the physical delivery of gas, they depend on short-term markets to trade out of their positions before the time of physical delivery [11]. While increased trading by shippers in the spot market is essential for financial players to trade out of their positions, shippers simultaneously depend on the financial derivatives that financial parties provide through the futures market to reduce the risks associated with shipping activities.

3.2.4. Data transparency and role of PRAs

Transparency and availability of data are necessary factors for instilling confidence in market players, which in turn will help develop market liquidity [26]. The availability of a variety of key market information, such as prices, infrastructure availability, and access terms and conditions, is a critical factor in preventing discrimination, boosting access and competition, and safeguarding efficient operation of the industry [20]. Such transparency of information on trade volumes, price quotations, and indexes is critical for market participants to trust the hub prices. However, even in Europe, with the exception of Britain and the Netherlands, there is still room for improvement with regards to data availability [8].

The reliability and transparency of the prices reported by the PRAs are critical in the development of a liquid gas market hub. PRAs have played an important role by assessing clear and transparent price and volume reporting [10]. Acceptable price indexes need to make market participants confident that the prices are true and reflect the value of gas at any point in time for that hub location [5]. The exchange price has limited impact given the fact that a large percentage of trading is conducted through OTC and other non-exchange mediums. Therefore, a neutral PRA is often needed to reveal the trading prices across the various trading avenues.

4. Case study of East Asia

Applying the framework in Section 3, we summarize the current stage of hub development in China, Japan, and Singapore (Table 2). The results show that Singapore is the front-runner in hub building, and Japan and China lag behind. Both Japan and China have yet to designate a clear trading point and instead only have exchanges. The success of Singapore, however, is dependent on the materialization of an LNG hub. Moving ahead, we briefly analyze the future of the three gas or LNG hubs in the three countries.

4.1. Singapore hub initiatives

Singapore has gone through all the necessary steps toward creating a gas hub, although it is an LNG hub rather than a gas hub. The establishment of infrastructure in the commissioning of the LNG terminal with an 11 million tones (MT) capacity and the business practices allowing for break bulk and trade of LNG are important steps. In 2014, physical LNG participants, together with the Energy Market Company and Singapore Exchange, initiated the free-on-board (FOB) Singapore SLInG, a spot index based on a weekly industry poll of major traders' assessments of a fair mid-price for Singapore FOB LNG cargo. The SLInG index is compiled as the average of prices submitted by LNG players who offer a fair assessment of LNG cargo prices in and around Singapore and prices assessed in terms of FOB Singapore [27]. As of December 2017, SGX had also launched three indexes in the SLInG Group: Singapore Sling, North Asia Sling, and Dubai/Kuwait/India (DKI) Sling, covering the entire Asian region [27].

The Singapore SLInG trading point is the waters in the vicinity of Singapore, while the Northeast Asia SLInG defines delivered ex-ship ("DES") to designated ports in Japan, Korea, Taiwan, and China as its trading point. For the DKI Sling, the Base Discharge Port is one of the named regasification terminals, located in a safe port in the "DKI Market" (Dubai, Kuwait, or India) [27].

Table 2
Comparative analysis of hub development in East Asia.

	Singapore	Japan	China
Establishment of trading point (hub); network, TSO, and storage	Virtual LNG hub is defined; gas hub could emerge if secondary gas market develops well. National network exists, TSO is independent. There is sufficient storage infrastructure for LNG reload and trading of cargo. TPA enabled.	The whole of Japan as a virtual hub. No national pipeline networks. No national TSO. There is a storage infrastructure in re-gas terminals. No independent storage.	Five pricing points for SHPGX do not have network foundation. Some national and regional transmission networks; TSO is not independent. Insufficient storage due to low price volatility.
Hub operator	Singapore Exchange is designated	JOE is designated	No designated hub operator
Trade platform/exchange	SGX operates the first LNG trading platform in Asia.	Tokyo Commodity Exchange (TOCOM) and JOE (OTC)	Shanghai and Chongqing exchanges
Specification of products	Spot, swaps and futures products have been specified.	Standardized physical forward products and cash settled swap products	Only spot trading. Not standardized yet.
Active spot market	No actual spot trading. Prices based on assessment of cargo.	No spot trading. Some trade in futures.	Active spot trading but prices more or less regulated.
Market players	Sufficient and diversified market players	Modest, but mainly Japanese players.	Sufficient number of market participants but all Chinese players.
Futures markets and products	Swaps exist; Futures in development.	Based on METI prices and JKM prices.	Little hope to develop one in the near future.
Price reporting agencies (PRA) and indexes	Indexes are provided by SGX. No involvement of PRA.	Japan Monthly Spot index by METI; Platts JKM index used to develop derivatives.	Trading prices reflect government set prices. No involvement of PRA in the two exchanges.

Source: Authors' summary based on analysis in Section 4.

A key factor in SLInG's potential success will be the number of market players involved in the price assessment process and how effectively the SGX operates, which will only become evident over time. Currently, there are more than 20 physical market participants in the SLInG assessment [27].

The development of a secondary gas trading market (SGTM) in Singapore has the potential to make up for the lack of spot trading in the LNG hub. The Energy Market Authority (EMA) has called for consultation on the development of the SGTM in Singapore [28]. An SGTM, a physical gas-trading platform that allows anonymous gas bidding and selling for same day or next day delivery, was proposed to allow for domestic gas price discovery in a liquid market that reflects Singapore's demand and supply conditions. Gas users are also able to complement their portfolio of long- and medium-term gas supplies so they can optimize their gas supply portfolios and mitigate price volatility. Since Singapore's gas market has been liberalized and the TSO is independent, an SGTM has the potential to bolster Singapore's position as a hub for LNG and gas trading activities and pave the way for the potential establishment of a forward market to trade financial contracts for gas [28].

4.2. Japan's hub initiatives

Japan's Ministry of Economy, Trade and Industry (METI) has proposed the creation of an LNG hub in Japan and for the region [29]. While Japanese domestic limitations are expected to be lifted by 2022, the limited liquidity of spot-traded LNG in a market where demand is declining and companies are over-contracted is a long-term constraint.

Due to the lack of a domestic gas network, Japan has followed Singapore's path in terms of the LNG hub concept. Even in the case of physical delivery [30], LNG will simply be diverted from one regasification terminal to another. While LNG derivatives have been standardized in Japan, the specification of a trading point has not been achieved so far.

METI has developed the Japan Monthly LNG Spot indexes to track contract prices for the LNG cargo delivered to Japan. It has been publishing the results of a monthly census distributed to LNG market participants since 2014 [31]. The price index applies to the shipping of any cargo size and delivery to any location in Japan. This means that there is no specific benchmark trading point and all of Japan is considered as the virtual trading point.

In November 2013, the Tokyo Commodity Exchange (TOCOM) established the Japan OTC Exchange (JOE), an over-the-counter market for oil products and LNG derivatives. JOE, supported by METI, has already offered non-deliverable forward LNG contracts, but only one deal was reportedly executed.

In addition, the TOCOM and PRA Platts have agreed to develop benchmark prices for Japan's domestic oil products and LNG in Asia. The agreement also sees them working together to accelerate the development of derivative products based on proposed benchmark prices with the aim of enhancing risk management and market transparency in Japan [32]. Another arrangement with the SGX explores joint development of products such as LNG derivatives, market distribution, and joint promotion of products [33].

Subsequently, JOE launched JKM-based LNG contracts in April 2017 [30]. The joint venture has devised specifications for a pair of LNG contracts, the first for the physical delivery of cargo and the other for cash settled swaps. This is a Japan-centric contract, with the price benchmarks underlying the

physical product being the Platts JKM price for spot contracts [30].

4.3. China's hub initiatives

Aligned with its expansion plans for the natural gas market, China is moving to create natural gas trading hubs. With strong physical volume and potential for volume growth as a foundation, it is speculated that hosting a benchmark price hub will have certain advantages, such as an increase in pricing power [34], a notion, however, that has been disapproved by a quantitative study [2].

There are two gas exchanges in China: the Shanghai Petroleum and Gas Exchange (SHPGX) and the Chongqing Petroleum and Gas Exchanges (CQPGX). The SHPGX was established in July 2015 and started full operation in November 2016, while CQPGX has yet to start trading gas as in December 2017. SHPGX initially traded pipeline gas and LNG for next day delivery without standard delivery points. Currently, it is widely believed that Shanghai will be the benchmark hub, with some scholars, such as Shi [13], challenging the idea.

CQPGX, the second gas exchange in China, was established on January 12, 2017. CQPGX plans to focus on short and spot trading in the initial stages and gradually introduce mid- to long-term futures trading [35]. As a gas producing region (particularly shale gas) with many large gas users and a good pipeline network, Chongqing has major advantages in developing a “Chongqing gas price” [13].

While Shanghai and Chongqing exchanges are competitive in nature, they could be potentially focusing on two different regions in China, the Eastern and South Eastern markets for Shanghai and Western markets for Chongqing. In addition, the market characteristics would compel the Shanghai hub to focus more on conventional pipeline gas and LNG trading while Chongqing focuses on the adjacent largest shale gas and coal bed methane resource-rich region in China.

However, so far, China has not established a gas hub. The five pricing points defined by SHPGX for its pipeline trade do not have the necessary underlying network infrastructure to be trading points. In September 2017, SHPGX organized pipeline gas trading by five regions (East, North, South, Southwest, and West) that are designated by CNCP sales branches. In each region, a provincial capital is designated as a pricing point. Therefore, there are five benchmark pricing points in China (Beijing for North, Shanghai for East, Guangzhou for South, Lanzhou for West, and Chengdu for Southwest). However, due to limited network capacity, gas traded at these points (even if considered to be physical hubs) is rarely transported among these points and within the regions that the pricing points represent; thus, the hubs are not functional.

Given that China is the world's third largest gas market and it has poor regional pipeline interconnections, it could host more than one benchmark price hubs. The US gas market had 38 gas hubs in 1998, many of which were consolidated into the present 24 hubs with two main benchmark prices. Chinese gas market development could also be similar to that of US and European hubs with multiple hubs developing and thereafter consolidating with multiple credible benchmark prices. Despite the media prominence of the Shanghai hub, all the major gas producing and consuming regions and transit points could be potential candidates for hubs. The Ningbo Commodity Exchange adopts the ICIS Asian LNG spot price assessment as a benchmark for its LNG forward trading. A northwestern gas hub in Karamay, Xinjiang province and a physical hub in Zhongwei are in discussion [13].

5. Conclusion

While there are many discussions on the transition of gas pricing mechanisms from oil indexation to hub indexation, there is often contradictory information on the concept of hubs and no public information on which key elements are needed to form a hub. This paper proposes a list of key elements and uses them to access hub development in China, Japan, and Singapore. The LNG hub concept is also discussed within this framework.

The literature survey suggests that nine key elements are necessary to form a hub. Some of these elements are common to all kinds of gas hubs, while others are more advanced elements for benchmark hubs. The trading point is the element that most resembles a hub. Defining such a trading point needs network infrastructure (underlying pipelines) and software infrastructure, such as the specification of the hub's governing rules and regulations, and the standardization of products and rules for balance. This latter element, however, is not necessary in the case of LNG hubs.

A hub operator, an exchange, and market participants are other key elements. For a benchmark hub, a benchmark trading point has to be designated. Derivatives markets, financial players, and price reporting agencies are also needed to create a credible benchmark price index.

Despite extensive interest and effort across East Asia in developing a gas or LNG hub, there are no functional natural gas or LNG market hubs. Singapore is leading the way in establishing a regional LNG benchmark hub. It has met all the requirements for an LNG hub with the only constraint being the slow development of the futures market and low volume of spot trading, both of which cannot be addressed at this stage. Japan is following a similar path to Singapore but is disadvantaged by its fragmented gas markets and declining demand. China, given its vast infrastructure and differing regional market characteristics, has the potential to build several gas hubs, but progress so far has been limited to the establishment of two exchanges. While SHPGX has defined five pricing points, the lack of a network foundation makes these points distant from functional hubs.

Thus, the creation of an East Asian benchmark gas hub faces significant challenges. The development of network infrastructure, the definition of a trading point, and the designation of benchmark hubs are also necessary in all three countries. The specification of spot and futures products and

further development of the futures market are required as well. Although Japan and Singapore have been on the path toward LNG hubs, it would also be useful to develop spot gas hubs by initiating secondary gas market trade in these countries.

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