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Key words

Upgrading mechanisms; knowledge bases; automotive industry; construction industry; China

JEL codes

L62, L74, N65, O31

1 Introduction

An important theme in the literature on innovation, learning and knowledge development is economic upgrading, also referred as 'sectoral upgrading', 'industrial upgrading' or simply as 'upgrading' (Milberg and Winkler, 2011). In its basic form, upgrading refers to 'innovating to increase value added' (Giuliani et al., 2005, p.522) and covers learning as well as knowledge sourcing (Van Tuijl, 2015).

The concept has been discussed in various approaches in different – sometimes overlapping – research fields. Firstly, in development studies the technological capabilities approach (Lall, 1992; Bell and Pavitt, 1993) deals with technological upgrading and learning by firms in developing countries. Likewise, the catching up literature analyses R&D and learning strategies of 'latecomer firms' in developing countries that try to catch up with competitors from advanced nations (Mathews, 2002).

Secondly, in the business literature, the competitiveness approach deals with upgrading in order to improve the competitive position of firms, clusters or entire nations (e.g. Porter, 1990). Another approach in this research field are studies on joint-ventures (e.g. Nam, 2011), discussing upgrading via technology transfer and learning through partnerships between foreign firms and domestic suppliers.

Thirdly, the global value chain approach, in fields like economic geography, international economics, and regional studies, deals with regional upgrading via global connections with other regions that enable technology and knowledge transfer within and between regions (e.g. Humphrey and Schmitz, 2002; Giuliani et al., 2005).

More recently, this approach does not only discuss upgrading of local suppliers due to interaction with global operating lead firms, but also with social upgrading, referring to the enhancement of living and working conditions of workers due to higher wages and labour rights (Barrientos et al., 2011).

In this article, we provide a new way to study upgrading by combining these different approaches dealing with the concept of upgrading and link them to the taxonomy of the differentiated knowledge bases. The knowledge base concept is used to explain differences in the geography of innovation in different industries. This concept puts forward that the possibilities to produce and transfer knowledge across geographical distance differ per industry, depending on the industry's dominant knowledge base, namely, analytical (science based), synthetic (engineering based) and symbolic (creative) knowledge (Asheim and Gertler, 2005; Asheim and Coenen, 2005; Asheim, 2007; Asheim et al., 2007). As we show in this article, the knowledge base concept can also be used to explain how the process of upgrading can take place, complementing other approaches explaining this process, such as the type of chain governance (Humphrey and Schmitz, 2002) and the industry type (Giuliani et al., 2005).

We draw empirical evidence from the automotive and construction industries in China. This is relevant because of China's large ambitions to upgrade its economy, and we contribute to the broad literature dealing with the debate about China's technological upgrading and learning (e.g. Liu and Tylecote, 2009; Xiao et al., 2013). We focus on upgrading of the synthetic and symbolic knowledge bases. The analytical knowledge base is especially relevant in science based industries – such as

bio-technology – and for basic research largely performed in developed countries, and is less important in engineering based industries (like automotive) as is shown in other studies on knowledge bases (Plum and Hassink, 2011; Van Tuijl and Carvalho, 2014; Van Tuijl, 2015). However, analytical knowledge creation is not irrelevant in the automotive (e.g. new material research to develop lighter vehicles) and construction (e.g. research on new building materials) industries. Analytical knowledge creation is particularly done in pre-competitive stages of research projects, which fall outside the scope of our analysis. Moreover, various studies on the automotive industry show that foreign car makers and suppliers tend to keep basic research in the home base, while R&D activities in China are limited to product adaptation due to a fear of knowledge leakage (Altenburg et al., 2008; Van Winden et al., 2010). Therefore, we do not include upgrading of the analytical knowledge base in our analysis. The central question in this paper is how does upgrading of the synthetic and symbolic knowledge bases take place?

To answer this question, we combine literature on knowledge bases and knowledge sourcing (e.g. Martin and Moodysson, 2011) with various approaches dealing with upgrading in order to discern a number of upgrading mechanisms – 'monitoring', 'mobility', 'learning-by-interacting in project teams', 'on-the-job training and learning in transnational corporations (TNCs)[1]', 'technology transfer', and 'learning-by-doing and -using' – used as frame to structure our analysis. Based on our empirical analysis, we identify a number of upgrading mechanisms for the synthetic and symbolic knowledge bases.

[1] TNCs are firms with value added activities in at least two countries (Dunning, 1993) and include small firms with a limited number of establishments (such as architecture studios) as well as large multinationals with activities at many places (e.g. car assemblers).

This article is organised as follows. Section 2 discusses the two theoretical concepts (knowledge bases and upgrading) and discerns a number of upgrading mechanisms used to frame our analysis. Section 3 discusses the research methodology, followed by our results and discussion in section 4. Section 5 ends with conclusions, policy implications and directions for future research.

2 Theory

2.1 Knowledge bases

Knowledge development and learning have become increasingly important for economic growth, not only in high-tech industries, but also in traditionally less knowledge-intensive industries, such as automotive and shipbuilding (Van Winden et al., 2010). This has led to a number of new theoretical concepts used to analyse innovation and learning in different industries, such as various modes of innovation (Jensen et al., 2007) and differentiated knowledge bases (Asheim and Gertler, 2005; Asheim and Coenen, 2005; Asheim, 2007; Asheim et al., 2007). These approaches are complementing each other (Van Tuijl, 2015). In this article, we use the taxonomy of the differentiated knowledge bases in order to explain how upgrading takes place.

The knowledge base approach – just like the various modes of innovation – has been set up as a response to criticism on other typologies to explain differences in innovation between industries, such as on the distinction between tacit and codified knowledge (Johnson et al., 2002), and on current science and technology indicators (Laestadius, 1998). Asheim and colleagues (Asheim and Gertler, 2005; Asheim and Coenen, 2005) first introduced the analytical (science based) and the synthetic

(engineering based) knowledge bases. Later, a third mode of knowledge creation (the symbolic knowledge base) was introduced by Asheim et al. (2007) in order to accommodate the increasing relevance of cultural production. The knowledge bases differ in the way of learning, the mix of tacit and codified knowledge, codification possibilities and the relevant spatial scale of interaction. In this paper, we are interested in upgrading of the synthetic and symbolic knowledge bases, and therefore, we briefly discuss the characteristics of these two knowledge bases into more detail.

The *synthetic* knowledge base refers to industrial settings where innovation is based on the use of existing knowledge and of new combinations thereof, aiming to solve concrete problems. Knowledge development takes place in an inductive process and typical activities include trial-and-error production, experiments, custom production and computer-based simulation. The outcome of the knowledge development process is highly concrete and visible, for instance in the form of prototypes. Examples are the development of new ships and adaptation of cars for specific markets (Asheim and Coenen, 2005). It concerns mainly applied research, or the 'D part' of R&D (Plum and Hassink, 2011), and the focus is on the adaptation of existing products and processes. Although the knowledge is partly codified, the dominant knowledge type is tacit and is based on concrete know-how, craft and practical skills. Learning is an interactive process with customers and suppliers (Asheim and Coenen, 2005) and is often dominated by industry-industry relations (Plum and Hassink, 2011).

The *symbolic* knowledge base refers to the aesthetic dimension of products, the development of images and designs, and to the economic use of cultural objects (Asheim et al., 2007). It can be distinguished mainly on its context specificity, in

contrast to the other knowledge bases which are based on differences in the degree of tacitness, formalisation and ultimate objective for knowledge creation (Martin and Moodysson, 2011). Symbolic knowledge is embodied in physical products, such as furniture, but the economic value differs from place to place due to its aesthetic character. It also includes forms of knowledge created and applied in service industries, like advertising, and is especially relevant for cultural industries, such as media and architecture (Martin and Moodysson, 2013). Innovation takes place via recombination of existing knowledge in new ways. Knowledge development is a creative process which emphases reusing or challenging existing conventions and is based on learning-by-doing, on-the-job training and often takes place in project teams and via interaction with other actors in the professional community (Asheim et al., 2007; Martin and Moodysson, 2013). Hence, learning takes place via informal and interpersonal interaction in professional communities. Similar to the synthetic knowledge base, and because of its strong cultural embeddedness, knowledge has a strong tacit component and is based on craft, practical skills and searching skills (Asheim et al., 2007).

The knowledge base approach has been used to explain the geographical configurations of knowledge interaction and innovation in various industries, depending on the leading knowledge base. Various empirical studies (e.g. Coenen et al., 2006; Moodysson et al., 2008; Plum and Hassink, 2011) show that synthetic knowledge tends to have a local dimension, meaning that it is sensitive for geographical proximity. Similarly, it is shown that symbolic knowledge is mainly generated through project-based work with interaction in localised networks (Martin and Moodysson, 2011; 2013). However, there is contrasting evidence that global

linkages play a role in developing symbolic knowledge as well (Manniche and Testa, 2010) and more factors than knowledge bases explain the geography of innovation in industries (Chaminade, 2011). Therefore, in reality, industries depend on combinations of all knowledge bases (Asheim and Hansen, 2009).

Recent studies (Moodysson et al., 2008; Van Tuijl and Carvalho, 2014) use the concept of the differentiated knowledge bases to compare various stages in innovation projects within a single industry, rather than comparing different industries. In addition, the concept is linked to different types of knowledge sourcing – formal collaboration; monitoring and mobility – as further explanation for differences in the geography of innovation between industries, as well as between innovation stages within the same industry (Martin and Moodysson, 2011; Van Tuijl and Carvalho, 2014). As we show in this article, the concept can also be used to enrich the upgrading literature by analysing the process of upgrading of the synthetic and symbolic knowledge bases. In the next sections, we discuss the concept of upgrading into more detail and we introduce a number of upgrading mechanisms.

2.2 Upgrading

Upgrading is a complex multidimensional concept that covers different approaches and lacks a uniform definition (Morrison et al., 2008). Before detailing our approach, we discuss a number of dimensions of the concept. A first dimension refers to different types of upgrading. The global value chain approach distinguishes five types of upgrading: i) product upgrading (making more advanced products); ii) process upgrading (using more efficient production processes); iii) functional upgrading (performing higher value added functions); iv) inter-functional or chain upgrading

(firms apply their skills in sectors that generate higher value added) and social upgrading (improving living and working conditions of workers) (Humphrey and Schmitz, 2002; Barrientos et al., 2011). Likewise, the technological capabilities approach acknowledges technological, managerial and organisational capabilities (Lall, 1992). However, despite the wide use of the types of upgrading, a critique is that the types are difficult to distinguish from each other as they are interrelated (Ponte and Ewert, 2009). In addition, economic upgrading can co-exist with social downgrading (Barrientos et al., 2011).

Secondly, different geographical scopes of analysis are discerned. Most of the studies in the upgrading literature focus on developing and emerging economies, but there are also studies of upgrading in advanced nations, like Norway (Isaksen and Kalsaas, 2009). Moreover, the seminal work of Bell and Pavitt (1993) compares upgrading trajectories in developed and developing countries. This is in line with the competitiveness approach that deals with upgrading in developing as well as developed countries (Porter, 1990).

Thirdly, different industrial scopes of analysis are distinguished in literature. Many case studies deal with traditional industries such as textile and footwear, but there are also cases of complex systems (like automotive) or specialised suppliers in more advanced sectors like software (Chaminade and Vang, 2008). Furthermore, comparisons of different industries show that the degree of upgrading is dependent of the type of industry (Giuliani et al., 2005) or on the sectoral innovation system (Malerba and Nelson, 2011).

Fourthly, upgrading can take place across various spatial and organisational configurations (Gereffi, 1999; Van Tuijl, 2015), ranging from local to global and from within a single subsidiary to networks between lead firms and suppliers and knowledge institutes. This is linked with a critique on the upgrading literature stressing that the exact unit of upgrading is unclear (Morrison et al., 2008). The technological capabilities approach combines the micro level (firm) with the national level (Lall, 1992), the competitiveness approach analyses the firm, cluster or national level (Porter, 1990), whereas the global value chain approach focusses on the chain level, in order to study upgrading of suppliers or regions (Humphrey and Schmitz, 2002). Hence, upgrading can cover various units of analysis.

Finally, upgrading is often difficult to realise, (Lorentzen and Barnes, 2004) and the degree of upgrading differs per case. In fact, there are several barriers hindering upgrading, such as a fear of knowledge leakage, limited learning capabilities, and property rights (e.g. Ernst and Kim; Xiao et al., 2013). Consequently, various conditions need to be met in order to realise upgrading. First, local actors need to be connected with global networks in order to have access to foreign markets and knowledge (Ernst and Kim, 2002). Second, upgrading requires the acquisition of new knowledge and skills which takes place via a process of interactive learning (Chaminade and Vang, 2008) or via observation of competitors (Porter, 1990; Malberg and Maskell, 2002). Therefore, upgrading is stimulated by an environment that encourages interactive learning as well as unintended knowledge spill-overs. The presence of specific regional assets, like skilled workers, or regional-specific market and technological knowledge, is another important requisite for upgrading (Ernst and Kim, 2002).

In sum, the upgrading literature is diverse in terms of geographical and sectoral scope, the unit of analysis, and in terms of (expected) outcomes. Nevertheless, a similarity in the different approaches is that upgrading attempts to increase added value (Giuliani et al., 2005). In this article, we focus on 'economic upgrading' - simply labelled as 'upgrading' (Milberg and Winkler, 2011) - that we perceive as a process to increase added value, taking place via different upgrading mechanisms that we obtain from the studies on knowledge bases and knowledge sourcing, and various approaches dealing with upgrading, being the technological capabilities approach (e.g. Lall, 1992), the competitiveness approach (Porter, 1990) and literature on joint-ventures (e.g. Nam, 2011). In the remainder of this section, we briefly specify these upgrading mechanisms.

2.3 Upgrading mechanism

The knowledge base literature discusses two upgrading mechanisms: 'monitoring' and 'mobility' (Martin and Moodysson, 2011)[2]. A third upgrading mechanism, 'formal collaboration', seems rather generic, and is therefore replaced by a number of more specific mechanisms distinguished in the upgrading literature, being 'learning-by-interacting in project teams', 'on-the-job training and learning in TNCs', 'technology transfer', and 'learning-by-doing and -using'. Most of these upgrading mechanisms have been discussed in prior innovation and learning literature in various fields, but we briefly discuss them from the knowledge base and upgrading perspectives.

[2] The knowledge base literature uses the terminology of 'knowledge sourcing mechanism' (Martin and Moodysson, 2011), but since upgrading covers knowledge sourcing as well as learning, we use the term 'upgrading mechanisms' (Van Tuijl, 2015).

'*Mobility*' as an upgrading mechanism refers to knowledge sourcing via recruitment of staff coming from other firms or knowledge institutes (Martin and Moodysson, 2011). In addition, it concerns learning and knowledge sourcing via staff exchange in corporate networks (Van Tuijl and Carvalho, 2014). Thus, it covers upgrading via staff transfer within as well as between firms.

'*Monitoring*' is an upgrading mechanism discussed in the literature on clusters (Porter, 1990; Malberg and Maskell, 2002) as well as in the theory on knowledge bases (Martin and Moodysson, 2011). It can be described as knowledge sourcing via strategic observation of competitors, suppliers and consumers.

'*Learning-by-interacting in project teams*' as discussed in the knowledge base literature refers to interactive learning via brainstorming in project teams (Asheim and Coenen, 2005; Van Tuijl, 2015). Learning-by-doing, -using and -interacting have been widely discussed in earlier innovation literature (e.g. Lundvall, 1992; Jensen et al., 2007) and in the technological capabilities approach (Lall, 1992). In many cases, it deals with interaction between firms and other actors in value chains or in innovation systems. In addition, project teams are regarded as important arenas for such interaction (Grabher, 2004). In this article, we focus on learning in project teams, and therefore we use the term 'learning-by-interacting in project teams'.

'*On-the-job training and learning in TNCs*' is an upgrading mechanism from the technological capabilities approach (Lall, 1992) that has also been widely discussed in the literature on joint-ventures in China (e.g. Chu, 2011; Nam, 2011). It concerns

learning taking place via training of Chinese employees in foreign subsidiaries of TNCs or via foreign experts that come to China to train their Chinese colleagues.

Technology transfer is another upgrading mechanism that we have taken from the technological capabilities approach and joint-venture literature (Lall, 1992; Chu, 2011; Nam, 2011). It refers to learning via transfer of equipment and machinery by foreign firms to domestic firms and knowledge institutes in China.

'*Learning-by-doing and -using*' is an upgrading mechanism that has been widely used in innovation studies and is also applied in the literature on various modes of innovation (Jensen et al., 2007) and the differentiated knowledge bases (Asheim and Coenen, 2005; Asheim et al, 2007). This way of learning takes largely place on the job, e.g. in processes of experimentation, testing work and during trial-and-error production, and is particularly relevant in projects dealing with the development of new products or the adaptation for existing products to new markets (Van Tuijl, 2015).

The upgrading mechanisms complement and sometimes may overlap each other. For example, 'on-the-job training and learning in TNCs' and 'technology transfer' are often part of the same joint-venture deal. We use the upgrading mechanisms to systematically analyse how upgrading of the synthetic and symbolic knowledge bases takes place. The next section details our research methodology, followed by our empirical analysis structured along the upgrading mechanisms.

3 Research methodology

3.1 Research context and case study selection

In order to identify the upgrading mechanisms for the symbolic and synthetic knowledge bases, we followed a multiple case study approach. Analysing multiple case studies makes it possible to include many different entities (e.g. different industries), and are more valid and generalizable than single-case studies, because findings are based on a larger variety of empirical evidence (Eisenhardt and Graebner, 2007; Yin, 2003). Multiple case studies also enable the researcher to investigate different contextual conditions (Yin, 2003) and to understand cause-and-effect relationships in real-life interventions that are too complex for a survey or experimental studies (Jensen and Rodgers, 2001). We have systematically analysed the upgrading mechanisms in two case studies in China[3], the construction industry[4] and the automotive industry.

We have selected these two industries in China as case studies for a number of reasons. First of all, both industries were selected as classical pillar industries by the Chinese state in the 1980's, which resulted in large investments in order to develop these sectors and to increase capabilities in these fields. Nowadays, they are still selected as pillars, but fitting under a new label, being 'energy conservation and climate protection' (i.e. development of clean-tech vehicles and energy saving buildings). Thus, both are important for upgrading strategies of the Chinese state.

[3] Throughout our analysis, we compared differences in the upgrading mechanisms across the synthetic and symbolic knowledge bases and not across the two industries. This is a domain for further research but is out of the scope of this paper.
[4] With the 'construction industry' we refer to the broader 'architecture, engineering and construction industry'.

Secondly, both industries draw on the synthetic and symbolic knowledge bases – the two knowledge bases that are central to this study – as discussed in earlier knowledge base literature. Asheim and Hansen (2009) classify the architecture and construction industry as dominated by synthetic knowledge, but confess that architects rely on a combination of synthetic and symbolic knowledge. In architecture and construction, symbolic knowledge is crucial since competition is largely based on concept innovation (Kloosterman, 2008), but for the realisation of the final product, engineering is also important (McNeill, 2005), confirming the importance of the synthetic knowledge base as well. Similarly, the automotive industry is mainly an engineering based industry (Moodysson et al., 2008), but symbolic knowledge gains in importance (Van Tuijl and Carvalho, 2014).

Thirdly, despite large differences, e.g. in the production process and governance, both industries are classified as 'complex product industries' (Giuliani et al., 2005) and a project based approach is used in the development of new products (e.g. cars or buildings) or for the adaptation of existing products for other markets. This enables us to analyse different upgrading mechanisms in the daily operations of companies as well as during development projects which are important arenas for upgrading (Van Tuijl, 2015).

Fourthly, many studies deal with upgrading in China. This is particularly the case for the automotive industry that has been widely debated in literature[5]. On the one hand, many studies show how foreign car makers and suppliers increase capabilities of domestic firms by training and technology transfer through joint-ventures (e.g. Nam,

[5] Please see Chu (2011) and Van Tuijl (2015) for detailed overviews of the upgrading literature in the Chinese automotive industry.

2011). However, other studies put limitations to the effects of the joint-venture strategy (Liu and Tylecote, 2009; Xi et al., 2009) and stress that technological capabilities of Chinese firms tend to remain low (Altenburg et al., 2008). We contribute to this debate by analysing how upgrading of the synthetic and symbolic knowledge bases takes place.

3.2 Data collection strategies

The empirical data for this article has been gathered through interviews that were conducted in Beijing and Shanghai during two international comparative research projects and a return visit to China. The first project concerns a study towards the development of manufacturing in a global-local perspective with a case study of the automotive industry in Shanghai. The second project is a study towards the role of design in cities with a case study of the development of design in Beijing. After these studies had been concluded, Shanghai was visited again in order to gather additional data for both the automotive as well as the construction industry.

In total 48 interviews were conducted, of which 20 in the automotive industry and 28 in the construction industry. We interviewed engineers as well as designers in order to provide insights into the synthetic as well as symbolic knowledge base. Interviewees include lead architects, policy makers, university professors, managers of car assemblers, car suppliers and engineering firms and other industrial experts. We had interviews with representatives of large multinationals (such as car makers and architecture engineering offices) as well as small firms (like design studios), and included Chinese, foreign, and Sino-foreign companies (e.g. joint-ventures) in order

to get detailed insights into upgrading mechanisms and barriers seen from various perspectives.

Interviewees were asked about their daily work and activities, development projects of cars respectively buildings, drivers and barriers for development, Human Resources policy and training, linkages with universities and other firms, and interaction with local and higher governments. The interviews were semi-structured and lasted between one and two hours. We complemented the interview data with secondary sources, like scientific publications on the two industries, press releases, corporate reports, policy documents, industrial magazines, and information from multiple companies' websites, and by attending two professional conferences.

4 Results and analysis

In order to structure our analysis, we follow the various upgrading mechanisms introduced in the theoretical section. For each upgrading mechanism, we explain how they contribute to upgrading of the symbolic and/or the synthetic knowledge bases supported by empirical evidence from the Chinese automotive and construction industries and discussed with existing literature.

Learning-by-interacting in project teams

Learning-by-interacting in project teams is a crucial mechanism to learn new styles, increase creativity, and thus, to upgrade the symbolic knowledge base. An important channel to do this is via brainstorming in multi-cultural project teams. Architecture studios and car design studios make use of multi-cultural design teams in order to mix

different styles and to develop new ones, as expressed by a German architect: "We need creativity. To get this, let's say when there are eight people, there are eight ideas which are thrown together". To give additional incentives to feed creativity, architecture firms as well as car makers form internal project teams which compete with each other. Chinese designers learn to work in these teams and to jointly develop new ideas. In addition, they learn new working methods, including joint-brainstorming and discussing.

As such, learning-by-interacting in project teams (and by hiring foreign designers, see next subsection) is important to overcome a barrier in the Chinese educational system that offers limited attention to group work, discussion and expression of ones' own ideas. Nearly all our interviewees acknowledged the Chinese education system as a serious barrier to develop creativity, and thus to develop symbolic knowledge.

In sum, 'learning-by-interacting in project teams' is an important upgrading mechanism for the symbolic knowledge base, which is also mentioned in earlier research (e.g. Asheim et al., 2007). Our evidence details that this is done via brainstorming between Western and Chinese designers in multi-cultural project teams and often taking place in design studios.

Mobility

Working in multi-cultural project teams already suggests the importance of international mobility for the development of symbolic knowledge. Chinese firms hire foreign architects and car designers to bring new creativity and working methods. As noted by the director of a Chinese construction company: "Many Chinese firms hire

foreign architects to do joint projects. They are also using foreigners as teachers. Chinese project partners learn from foreign architects by continuously raising questions and by observation". Foreign designers are also used by Chinese firms in order to win projects, as many clients prefer foreign architecture that has a higher status. Likewise, many Chinese car makers, hire foreign designers to design Chinese models and to develop Chinese brands in order to escape from price competition and to reach higher market segments, and thus, to upgrade Chinese firms by improving the symbolic knowledge base. For instance, Great Wall, Chongqing Changan, Geely, CH Auto Technology Corp, Beijing Automotive, Brilliance and Qoros, all hired Western designers hoping to increase the quality of design in China by 'a foreign touch'(Automotive News Europe, 2012).

Upgrading through mobility is also possible through recruitment of Chinese employees who with international experience. Many Chinese architects study or work abroad and return to their home country in order to work for Chinese offices or to start their own business. Many Chinese architecture firms have principals who studied abroad, receive international trainees, and have a large share of foreign architects. They do this to get fresh ideas from all over the world and to learn new styles. On the other hand, the use of Chinese architects by foreign firms in China is crucial to link global ideas with the local context, as put forward a Dutch architect: "We have one Chinese designer who is project leader of all our projects in China. She speaks the language and knows how to deal with Chinese clients." As such, foreign companies can also learn from Chinese colleagues.

Similarly, the Chinese automotive industry has a strong international character with mobility as an important mechanism to bring in new knowledge. This does not only refer to mobility within joint-venture (JV) partners as widely discussed in other literature (e.g. Nam, 2011; Van Winden, 2010), but also to job transfer between foreign companies and domestic companies. For instance, about half of SAIC Motor Technical Centre's employees worked for a foreign company before. Nowadays, many Chinese engineers move from foreign and JV firms to Chinese firms, as put forward by a manager of a JV firm: "Especially state owned firms are popular employers nowadays. They can offer more than Western firms: a higher salary and more job security." The transfer of engineers to Chinese firms suggests that labour mobility is important for the development of synthetic knowledge, although often in a longer time period as job rotation of engineers is generally lower than of designers.

To conclude, mobility is an important upgrading mechanism for both symbolic as well as synthetic knowledge, as is also observed in the existing knowledge base literature (Martin and Moodysson, 2013). In line with other studies stressing the importance of fast job rotation of designers (e.g. Kloosterman, 2010), we have shown the importance of foreign car designers, architects and trainees, and Chinese employees with international experience for bringing new styles and generating new ideas to develop symbolic knowledge. Concerning the synthetic knowledge base, we have also identified mobility as an upgrading mechanism, especially in the automotive industry between JVs and state-owned firms. Also other studies dealing with synthetic knowledge based industries, such as ICT (Saxenian, 2005), show the importance of mobility for upgrading.

However, we also observed limitations regarding upgrading via mobility, especially concerning the symbolic knowledge base. Firstly, the strategy of hiring foreign designers creates a dependency on external expertise. In both industries, due to a relatively low level of creativity of Chinese designers and the good reputation of Western designers, concept design – the most creative part of the design process – has been mainly done by Western designers. Especially in niche markets, such as villas and mega projects in the construction industry, concept design has been done by foreigners: "I do not want to be arrogant, but the fact that we won a major international competition in Canada is largely due to my work and some other foreign architects" (Austrian architect working for a Chinese architecture studio). Similarly, the luxury car segment is still dominated by Western car makers like Audi, Mercedes and BMW. Secondly, various interview partners explained that experienced Western designers and return migrants face difficulties in applying their aesthetical skills and working methods due to a focus on commercial values and institutional barriers including bureaucracy and censorship.

On-the-job training and learning in TNCs

Training and learning in TNCs are important upgrading mechanisms for both knowledge bases, but take place in different ways. The development of synthetic knowledge takes especially place via formal courses and on-the-job training of engineers in China as well as abroad in other subsidiaries of TNCs. This becomes particularly clear in the automotive industry. For instance, in SAIC-GM, foreign engineers train their Chinese colleagues in plants and research centres in China, while Chinese engineering teams travel around the GM network to do courses and to learn from their colleagues abroad. In addition, GM spreads new concepts in its network

and subsidiaries have the possibilities to learn: “Chinese engineers can learn from their foreign colleagues and the other way around ... They are one big team” (SAIC engineer). Other car assemblers and suppliers we analysed are using the same strategy and do this to reach the required international quality standards, contributing to upgrading of Chinese firms.

The development of symbolic knowledge is different. The main upgrading mechanism is learning and brainstorming in multi-cultural project teams, as described earlier, while formal training courses are less relevant, as becomes clear from our interviews in the construction industry: “The best moment to hire architects is when they leave university. In this stage, they are still fresh and have fresh ideas” (manager Chinese engineering firm). He continued that this is a large contrast with engineers: “They are, I would nearly say, useless when they have finished their study and need to learn on-the-job. This is a long and expensive learning process, and therefore we want to keep the best engineers”.

Concluding, the different ways of on-the-job training and learning in TNCs leads to upgrading of both knowledge bases, in line with the existing knowledge base literature (Asheim et al., 2007). The importance of on-the-job-training is also widely discussed in studies dealing with the Chinese joint-venture policy in which foreign firms are obligated to give Chinese firms access to their technologies and to train engineers and workers of Chinese JV partners and suppliers (e.g. Van Winden et al., 2010; Xi et al., 2009), despite doubts about the efficiency of this policy tool for more advanced forms of upgrading (Nam, 2011).

Technology transfer

Technology transfer between Western and Chinese firms is a crucial upgrading mechanism for synthetic knowledge development. It is a major requirement in JV deals in the automotive industry and has helped Chinese firms in especially product and process upgrading since the start of the modern Chinese automotive industry with the entrance of Volkswagen in the 1980's. Nowadays, Chinese firms take a more pro-active approach to obtain foreign technologies by taking over Western firms like Rover, Volvo and parts of Delphi. This gives Chinese firms not only direct access to modern technologies, but also control, an aspect which was missing in the JV agreements. This is in line with other JV literature of the Chinese automotive industry (e.g. Van Winden et al., 2010; Nam and Li, 2013).

In the construction industry, technology transfer seems to be less relevant as Chinese engineering firms and research institutes have good engineering facilities and skills, as put forward in our interviews: "Local institutes have modern test labs with the newest technologies. I wish we had such facilities in Italy" (Italian architect). Moreover, local experts and institutes are used by foreign firms as they have a large understanding of the local context and access to political networks. Even though firms in the construction industry are formally not obliged to cooperate with local partners, many do so in order to get licenses and local knowledge, for instance, as stressed in an interview: "There are many different licences for different construction works, like buildings in the chemical industries, headquarters, bridges ... Therefore we have many local partners" (vice director DHV China).

Chinese policy makers use the interaction between foreign and local firms in order to learn new concepts and working methods. Moreover, local institutes that check proposals act as 'gatekeepers' between local and foreign firms by passing documents between the actors, including local actors which are outside partnerships with foreign firms. This is an easy way for Chinese firms to obtain foreign (codified) knowledge, although it is not clear to what extent this leads to upgrading of synthetic or symbolic knowledge bases, as codified knowledge is less relevant for these knowledge bases (Asheim et al., 2007).

Summarising, technology transfer is relevant for upgrading of synthetic knowledge. This happens directly via technology transfer between JV partners and through foreign acquisitions by Chinese firms.

Monitoring

Monitoring is an important upgrading mechanism to develop the symbolic knowledge base. It is a crucial tool to get inspiration and creativity needed to develop new products or to get insights in specific market requirements. This happens in different ways and having various geographies. One the one hand, car designers and architects walk around in large Chinese cities to analyse specific Chinese architecture styles and cars models of competitors, and to observe what Chinese consumers are doing. On the other hand, designers get new inspiration from other places, obtained from watching movies, browsing internet, books and magazines, and by travelling around, as has become clear from our interviews in the construction industry, such as: "Designers need to travel around to get inspiration and to see other cultures and trends" (Italian architect), or "the idea <for a new roof> of our lead architect comes from a movie in

which he saw a dome that protects against viruses" (representative Chinese design firm). Likewise, in interviews in the automotive industry the importance of monitoring through various (digital) media and travelling around (e.g. visits to trade fairs) were mentioned as important ways to develop creativity.

To conclude, monitoring is especially relevant for upgrading of the symbolic knowledge base as also mentioned in the knowledge base literature (e.g. Asheim et al., 2007). We have found that the development of new creativity - through monitoring - has a local as well as a global dimension, as also mentioned in other studies on architecture which stress that concept design can be done 'everywhere', and 'designing at a distance' is taking place more frequently (Faulconbridge, 2009). This seems to contradict with the knowledge base literature that stresses that symbolic knowledge is highly dependent on the local context (e.g. Asheim *et al*., 2007; Martin and Moodysson, 2011), although some studies also suggest that symbolic development has a global dimension as well (Manniche and Testa, 2010).

Learning-by-doing and -using

Upgrading trough 'learning-by-doing and -using' is an important upgrading mechanism for the synthetic knowledge base. It takes particularly place during projects dealing with experimentation and testing work in order to develop prototypes and to adapt products (cars or buildings) to the Chinese context, including legal and technical standards and specific consumer requirements. This is especially the case for the construction industry, where global concepts need to be adapted to local contextual factors (McNeill, 2005), such as policy, climate, client requirements, culture and available construction materials. As illustratively put forward by a Chinese architect

about the concept of eco-cities: “All our projects are tailor-made products. There is a high dependency of local resources and the wishes of clients differ per case. Eco-cities can therefore not simply be copied from other places.” Also in the automotive industry some product adaptation and local testing takes place, even though cars and new models are often exported from one place to the other. For instance, new car models are tested in the home base, but also in new markets, on public roads or on specific test tracks. Another example is that various luxury car makers (including BMW, Audi and Daimler) offer larger models in the Chinese market for customers who want to be chauffeured, requiring extension of the existing models (Automotive News Europe, 2010).

Product adaptation is largely done by engineers, who make sure that new products work from a technical point of view and fit in the local context. Thus, it contributes mainly to synthetic knowledge development. The role of designers is limited to safeguarding of designs. Adaptation to local conditions may even hinder symbolic knowledge development. This is common in both industries where initial sketches and ‘wild ideas’ of designers (symbolic knowledge) need to be translated into concrete products fulfilling all kind of technical and market requirements, as explained in various interviews. This hinders creativity in particularly in early stages of projects all over the world, but in China in later stages as well. As explained by an Austrian architect: “China and Europe are two extreme worlds. In Europe, the client provides an extensive document with all requirements (a thick package of papers) at the start of projects, while in China the initial input from the client is limited (say one page). Other requirements in China are given in further stages. This changes ideas continuously and in the end your idea is completely gone”.

Product adaptation is mostly done in China and with support of local experts who have a larger understanding of the local conditions. As such, it be regarded as a mutual learning process, but we also found some contrasting evidence. For instance, testing work in the automotive industry in China concerns mainly adaptation of existing products. Testing of more advanced products is still performed in the home base of foreign car makers or in high-tech hubs, like Tokyo or Silicon Valley. This is done for secrecy reasons and the fear of knowledge leakage. Another example (from the construction industry) is very specific testing work, requiring specific knowledge not available in China. As illustratively put forward by a Dutch architect about testing of a new hydraulic concept: "In this project we used a Dutch knowledge institute as it is widely accepted to have a Dutch water certificate. In other cases, we use local specialists to obtain the right certificates". Both examples show limitations to the degree of upgrading via 'learning-by-doing and -using' during product adaptation projects in China.

In conclusion, 'learning-by-doing and -using', taking place during trial-and-error production in product adaptation projects, is important for upgrading of the synthetic knowledge base, confirming earlier knowledge base literature (Asheim and Coenen, 2005; Van Tuijl and Carvalho, 2014). Moreover, trail-and-error production can function as a barrier for symbolic knowledge development. We have also shown that testing work is largely done in China and is regarded as mutual learning process, albeit with limitations, which is in line with other upgrading literature (e.g. Xiao et al., 2013).

5 Conclusion

In this paper we have contributed to the upgrading literature by providing a novel analytical approach. By combining various approaches dealing with upgrading and linking these to studies on knowledge bases and knowledge sourcing, we discerned a number of upgrading mechanisms that we have used to show how the process of upgrading of the synthetic and symbolic knowledge bases take place. We illustrate our new approach with empirical evidence from the Chinese automotive and construction industries.

Our empirical results show that the main upgrading mechanisms for the synthetic knowledge base include 'technology transfer', and 'learning-by-doing and -using', while upgrading of the symbolic knowledge base takes place via 'learning-by-interacting in project teams' and 'monitoring'. 'On-the-job training and learning in TNCs' and 'mobility' are the main upgrading mechanisms contributing to the development of both knowledge bases, but working in slightly different ways. Table 1 summarises our main findings and presents explanations of how the upgrading mechanisms operate per knowledge base.

<Table 1 about here>

The findings of this study provide further insights into our general understanding of upgrading processes. Firstly, we provide new empirical evidence for 'projects' as organisational configuration for upgrading, following other literature on the geography of knowledge sourcing (e.g. Bathelt and Cohendet, 2014). We show that projects are important for upgrading of the symbolic knowledge base via 'learning-

by-interacting in project teams', while synthetic knowledge development takes place in product adaptation projects via 'learning-by-doing and -using'. This can be linked with more recent knowledge bases literature (Moodysson et al., 2008; Van Tuijl and Carvalho, 2014) dealing with knowledge sourcing in innovation projects, which we use as a plea for further research to analyse upgrading of different knowledge bases in projects.

Secondly, besides differences in knowledge bases, our results can be linked with other factors explaining the degree to which upgrading takes place. One key factor is the R&D strategy used by foreign firms (Chen, 2008) or by domestic firms (Mathews, 2002). Our results suggest that most foreign companies invest in product adaptation rather than in basic research, activities that are still done in the home base or specific R&D hotspots. Most Chinese firms we studied try to catch up by hiring foreign designers or by foreign take-overs. These might be useful strategies to catch up quickly, but the result on the long run is questionable. Therefore, a different strategy might be more useful in a further development stage (Xiao et al., 2013).

Thirdly, our results contribute to the literature dealing with the debate on China's technological upgrading and catching up (e.g. Nam, 2011). We provide further evidence of increased capabilities by Chinese firms, and that upgrading is a mutual learning process (Herrigel et al., 2013). This upgrading process takes place via various upgrading mechanisms (see Table 1). In addition to limitations to upgrading in China in other studies (e.g. Xiao et al., 2013), we stress that upgrading of symbolic knowledge remains a challenge, especially regarding the limitations of upgrading via mobility. In line with Brandt and Thun (2010) our results indicate that higher market

segments in both industries are addressed by foreign companies or by foreigners working for Chinese firms. However, by doing so, Chinese firms may still remain dependent on foreign expertise.

Our observations provide some policy implications for facilitating upgrading. First, we suggest emphasising teamwork and creative thinking in educational and training programmes, since teamwork and creative thinking are crucial for the development of symbolic knowledge. Furthermore, the importance of international mobility and training abroad indicates that the support of students and workers to go abroad on the one hand and investments in the home base to attract return migrants and expats on the other hand are crucial to benefit from these upgrading mechanisms (Saxenian, 2005). This also means further reduction of institutional barriers that hinder travelling from and to China. Similarly, reducing bureaucracy and censorship are important to increase possibilities for monitoring, again important to develop symbolic knowledge.

As this is only a first attempt to link knowledge bases with upgrading, further research and conceptualisation is desired. Firstly, as we have focused on the symbolic and synthetic knowledge bases only, we have not investigated the upgrading process of the analytical knowledge base. We propose conducting more research in science-based industries. Secondly, as we analysed two complex product industries, it is worth studying upgrading mechanisms and knowledge bases in other types of industries as well, being traditional manufacturing, resource-based industries and specialised suppliers (Giuliani et al., 2005). Thirdly, it would be worthwhile to perform research in countries with different political systems, since China is a specific case with a large domestic market and a powerful government that can determine different, industry

contingent upgrading criteria (Brandt and Thun, 2010). Finally, as we focus mainly on upgrading by studying interaction within firms and JVs, we suggest to analyse the upgrading mechanisms also in relation to interaction between firms and other actors in value chains and innovation systems, such as suppliers, clients and knowledge institutes.

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Table 1: Upgrading mechanisms per knowledge base

Knowledge base	Upgrading mechanism	Explanation
Symbolic	Learning-by-interacting in project teams	Brainstorming in multi-cultural teams, often taking place in design studios Interacting between foreign and Chinese designers leading to new creative ideas Chinese designers learn new styles and working methods
	Mobility	Job transfer of designers and trainees, often short term Recruitment of Chinese designers with foreign experience as well as foreign (lead) designers Foreigners and Chinese designers with foreign experience act as trainers and bring new creativity and working methods
	On-the-job training and learning in TNCs	Learning via working in project teams
	Monitoring	Development of new ideas via observation of competitors, consumers and other products Inspiration comes via observation in the direct local surrounding as well as from other places via travelling abroad and through (multi) media
Synthetic	Mobility	Job transfer of engineers on the medium and long run Job transfer within JVs, and between foreign companies and domestic companies Foreign engineers or Chinese engineers with foreign experience bring new knowledge
	On-the-job training and learning in TCNs	Training courses at other places in TNCs Foreign engineers as trainers in China
	Technology Transfer	JVs are set-up for technology sharing Access new technologies by foreign take-overs
	Learning-by-doing and -using	Testing work, trial-and-error production and product adaptation for the Chinese market Largely in China, mutual learning takes place