Ten Brink, Tobias; Butollo, Florian

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A great leap? Domestic market growth and local state support in the upgrading of China's LED lighting industry

FLORIAN BUTOLLO* AND TOBIAS TEN BRINK†

*(corresponding author) Friedrich-Schiller-University Jena,

Institute of Sociology, Carl-Zeiß-Straße 2,

07743 Jena, Germany

florian.butollo@uni-jena.de

†Jacobs University Bremen, Social Sciences & Humanities,

Campus Ring 1, 28759 Bremen, Germany

t.tenbrink@jacobs-university.de

Abstract *In this article we analyse the conditions for industrial upgrading in the Chinese LED industry, which proactive local state policies and expanding domestic markets have greatly facilitated. State initiatives provoked overinvestment, but eventually led to the emergence of competitive domestic enterprises. Simultaneously, firms benefited from a growing domestic market on which they outcompeted foreign companies in mid-price segments. The combination of these factors accounts for the peculiarly Chinese upgrading experience. Neither the resources provided by a new version of the 'developmental state' nor domestic market growth alone can explain the Chinese players' success. Based on these results, and given that the emerging economies have become the most important markets for certain consumer goods – a development that (local) industrial policies for industrial upgrading can influence – we provide further proof that it is necessary to rethink the export-led upgrading paradigm in theories of globally dispersed production.*

Keywords CHINA, GLOBAL COMMODITY CHAINS, GLOBAL PRODUCTION NETWORKS, GLOBAL VALUE CHAINS

Calls for a refurbishment of the Chinese economy are now ubiquitous, for there is a widespread belief that the Chinese 'global factory model' (Ernst 2008) has reached its limits (World Bank 2013; Yang 2012). As a response, the Chinese government has put the issue of *industrial upgrading* high on its agenda. The government particularly strives to develop new technologically advanced industries with a view to developing global leaders, an aim that ranked high in the twelfth five-year plan (2011–15), which

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singled out ‘strategic emerging industries’ (SEIs) as deserving particular support – a programme that was replicated on local levels.

In some of these industries, Chinese companies have been remarkably successful recently at enhancing their technological capabilities and gaining market shares globally. The LED lighting industry, which the government of Guangdong province classified as an SEI, is a case in point. Within a few years, China emerged as one of the largest producers in a market dominated by multinational companies. Quantitative growth thereby was coupled with improvements in lighting efficiency, the main indicator of technological maturity in the industry.

In this article, we track the development of this industry and ask about the conditions of its successful trajectory. Our thesis is that Chinese companies were able to expand in this high-tech industry despite being technologically behind their foreign competitors because they could both draw on multiple forms of mostly local state support and exploit opportunities in a growing domestic market for LED products, particularly in the mid-quality segment. The combination of these factors is what accounts for the peculiar upgrading experience in this sector, rather than merely the resources that a new version of the ‘developmental state’ is able to provide; in addition, domestic market growth alone would also not explain the success of the Chinese players. As such, the case of the LED industry may indicate a diversion from the market-driven export-led upgrading experiences that reflect a general shift towards markets in the Global South (Cattaneo et al. 2010; Gereffi 2014; Herrigel 2015).

Our findings from the LED industry have important implications for theories of industrial upgrading in developing countries. Discussions on industrial upgrading in recent decades have been characterized by a retreat from state-centric views of development and a focus instead on opportunities for knowledge transfer through inter-firm linkages (Gereffi 2005; Yeung 2014). While this paradigm shift paved the way for a refined understanding of disintegrated production networks in present-day globalization, it also implied an ‘export-bias’ in which domestic factors affecting development – particularly state apparatuses and markets – were neglected (Lee et al. 2014; Navas- Alemán 2011; Zhou 2008). In a ‘post-Washington Consensus world’ (Gereffi 2014), in which emerging economies have become engines of growth on the one hand and the most important markets for consumer goods on the other, theories of industrial upgrading once more need to be modified. At least in large territorial states, the domestic market – and not only exports – becomes an important growth driver and industrial policies may regain some of the potency they had lost through the disintegration of firm networks that lay beyond the reach of their territorial boundaries (Yang 2014, 2015; Yeung 2014: 80–1). Given that state support in China is largely driven by competition between local governments, the result is not a remake of the old (centralized) developmental state, but a novel synthesis between industrial upgrading in global value chains (GVCs), domestic development trajectories and a stronger role for industrial policies on various administrational levels.

We shall illustrate how this constellation can have beneficial effects on industrial upgrading by referring to the case of the Chinese LED lighting industry. To carve out the peculiarities of China’s LED trajectory, we draw on interview data, statistics,

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government documents, reports by LED associations, and business media analyses. We complement this with data from a field study in Guangdong. These included a sample of six LED companies, twenty-one in-depth interviews with leading representatives of industry, firm managers and local government officials in 2010, 2011 and 2013, and four follow-up interviews in 2014.[1] Since reliable quantitative data are still only sparsely available for the sector, we chose this multiple-strategy approach to allow for more diverse ways of analysing the material.

We have organized the remainder of this article as follows. First, we review the literature on industrial upgrading and make the theoretical argument for an assessment of the role of domestic market growth and state policies for upgrading. In the second section, we introduce the general structure of and recent shifts in the LED industry, before going on, in the third section, to look at the development of the Chinese LED industry per se. Fourth, we describe and discuss proactive local state policies to foster the industry and large domestic firms. Fifth, we look at the role of the domestic market as a driver for upgrading. Then, to conclude, we review our main findings and ask about the generalizability of the Chinese trajectory, namely whether we are witnessing the emergence of a new development model based on stronger state involvement and domestically centred regional value chains.

The role of the domestic market and (local) state policies for industrial upgrading

The prevalent theoretical models for analysing geographically dispersed production networks equated economic development with industrial upgrading through technology transfer from (mostly Western) lead firms to suppliers in developing countries (cf. Bair 2005; Navas-Alemán 2011). This reflected the dominance of transnational companies (TNCs) from advanced economies across most industries and the corresponding prevalence and partial success of market-oriented export-led strategies by firms in developing countries. Against the backdrop of this empirical development, the GVC framework developed a strong focus on forms of *governance* of value chains as the main factor affecting the ability of suppliers to upgrade, whereas the role of government policies, as well as the role of local consumer demand, remained understudied (Zhu and Pickles 2013: 44–5). In contrast, the GPN paradigm explicitly perceives governments as actors (Henderson et al. 2002: 447), but typically does not go on to elaborate in detail the role of state involvement for upgrading.[2]

The shift from import-substitution industrialization to the development paradigm of industrial upgrading in global value chains reflected the globalization of production. However, the emergence and increasing quantitative relevance of markets in developing countries resulted in the advent of a new theoretical paradigm, which emphasized the relevance of consumption in emerging economies and 'South–South trade' (Cattaneo et al. 2010; Gereffi 2014). Developing countries are no longer solely exporters of components and finished goods to markets in the Global North, but have become the fastest-growing consumer markets in their own right. As some recent contributions outlined below document, this quantitative shift in global market composition has qualitative implications for industrial upgrading in developing countries. This

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is due to factors such as different consumer preferences (which domestic firms can more easily meet), a growing proximity between producers and consumers (facilitating the development of apt designs by local companies), and a potential overlap of entities that issue industrial policies and regulate local markets (enhancing the steering capacity of states). In this contribution, we want to illustrate the implications of shifting end markets by referring to the case of the Chinese LED industry, which shows how an environment of expanding domestic markets and government intervention can have beneficial effects on a firm's upgrading performance. We thereby build on contributions that point to new upgrading possibilities in a 'post-Washington Consensus world', although in our view they have so far been insufficiently spelled out theoretically.

In terms of the role that *domestic markets* can play in upgrading firms, some authors go beyond merely acknowledging the sheer volume of South–South trade to emphasize the specific properties of such markets. These constitute unique advantages for local producers, namely opportunities to adapt products to consumer preferences, lower entry barriers for brand building, and advantages of local industry linkages (Brandt and Thun 2010; Gu et al. 2009; Zhou 2008). The domestic market can serve as a test-bed market in which local producers introduce indigenously designed products. Local firms can benefit from their proximity to markets that enable them to acquire knowledge about consumer preferences. In particular, competition with foreign companies in growing medium-range or 'good-enough' markets can enhance their technological capabilities (Brandt and Thun 2010; Gadiesh et al. 2007; Nölke et al. 2015).

Due to this specific composition of home markets, domestic companies may find better opportunities for *functional upgrading* through creating their own brands, despite the ongoing lags in terms of technological capabilities that would prohibit such steps on international markets. In the case of Brazil, Navas-Alemán (2011) reports a bifurcation of upgrading experiences in which domestically centred companies advance in functional upgrading while export-oriented ones engage in upgrading due to technology transfer and enhanced quality requirements by foreign lead firms. As Zhou shows with reference to the Chinese high-tech brands Lenovo and Huawei, both paths can intermingle and synchronize when domestically oriented companies tap supplier networks in the export value chains. They do this to offer technologically advanced products on the domestic market, which at the same time provide the foundation 'to move directly into own-brand manufacturing rather than moving progressively from manufacturing others' brands to creating their own (OEM to OBM)' (Zhou 2008: 2359). The growing importance of the domestic market also means that one should not understand upgrading as a one-way street of technology transfer from advanced to developing economies. Some Chinese producers, for instance, have been strikingly innovative in terms of manufacturability and product designs based on their ability to adapt to consumer needs, especially in medium-tech market segments. Thus, a mutual learning dynamic is taking place between foreign lead firms and their Chinese suppliers in sectors such as mechanical engineering, automobiles and solar panels. This in turn increases the probability of technological cooperation and the inclusion of emerging market producers in global innovation networks (Herrigel et al. 2013; Nahm and Steinfeld 2014).

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Moreover, thriving domestic markets serve as a magnet for foreign direct investment (FDI). This was evident in China throughout the reform period in which the government traded market access for technology transfer (Holweg et al. 2009; Liu and Dicken 2006). With the recent expansion of large private consumer markets, foreign firms have radicalized their investment strategies according to the dictum 'produce where you sell' (Herrigel 2015) and now engage in direct partnerships with promising domestic firms that the local authorities support and that possess knowledge of domestic consumer preferences (Yang 2014, 2015).

Due to these factors, the dynamic growth of domestic markets can turn out to be a game changer for industrial upgrading in large territorial economies and may serve as a stepping-stone for creating internationally competitive firms. In this sense, the emergence of a 'globalization with Chinese characteristics' (Henderson et al. 2013; ten Brink 2013), in which Chinese brands become global players after an incubation phase on the domestic market, is directly linked to the discussion about the peculiar conditions for industrial upgrading in China.

Since the GVC framework tended to neglect the role of state support for industrial upgrading, the theoretical debates on this matter are controversial. In the case of China, some contributions have highlighted beneficial interactions between state policies on the one hand and technology transfer in global production networks on the other (Chu 2011; Di Tommaso et al. 2012; Yang 2014; for sceptical views see Brandt and Thun 2016; Chen and Ku 2014; Yeung 2014; Zhou 2008). This especially accounts for the designated SEIs. Analyses of the nanotechnology sector (Huang and Wu 2012), the IC design sector (Ernst 2014; Ernst and Naughton 2012), the photovoltaic industry (Gruss and ten Brink 2016), and the Liquid Crystal Display industry (Yang 2014) demonstrate how various measures – subsidies, investment and tax policies, state consumption, technology support – helped to back up domestic companies.

In particular, research has highlighted the role of *local state actors*. As political scientists have shown, the state in China is not an all-powerful, centralized steering bureaucracy (McNally 2012; Yang 2004). Rather, local state competition prevails. Against the backdrop of capitalist dynamics, local governments compete over public investment and support for upgrading. Because a local official's potential to be promoted within the party hierarchy is closely connected to 'economic achievement', officials have a stake in supporting companies in their upgrading efforts. Moreover, instead of describing a monolithic state-directed form of development, recent studies focus on the interactions between local industrial policies and market-driven processes, a 'bottom–up, market-led approach to industrial policy' (Ernst 2014).

Based on these considerations, we acknowledge that industrial development in China takes place under peculiar conditions: the Chinese high-tech industry is thoroughly integrated into global production networks; in addition, it can draw on advantages through the growth of the domestic market and initiatives, especially those of local state actors that support upgrading. Due to the *combination* of these factors, industrial upgrading in China takes place under markedly different circumstances from those of other latecomer economies, including Taiwan, South Korea and Hong Kong.[3] The aim of our analysis is to discover how this new constellation affects the scope and

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the outcomes of industrial upgrading, and whether it fostered the emergence of competitive Chinese companies in technology-intensive segments. In the concluding section of this article, we discuss how far the Chinese can be generalized to a degree that would justify a modification of theories of industrial upgrading.

LED industry reshuffling and market entry of Chinese firms

The mass production of LED products, which began around the mid-2000s, has triggered massive changes in the lighting industry. As LED lighting, unlike traditional incandescent lighting, is based on semiconductor technology, traditional players needed to adapt. At the same time, new players with privileged knowledge of semiconductor technology entered the market. The profound shift towards LED technology has transformed conventional production methods. As such, it has opened opportunities toupgrade Chinese firms and to bring about a further regional shift of the industry towards East Asia.

The technological rupture implies shifts in the vertical division of labour within the LED value chain (see Figure 1).[4] The first segment, *upstream* production, refers to the manufacturing of 'epitaxial' wafers, which are coated with various layers of semiconductor compounds employing so-called MOCVD (metalorganic chemical vapour deposition) reactors. These wafers are then cut into chips, the core element of LED light sources. Next, *midstream* production refers to the subsequent production of ready-made light sources through the process of encapsulation, also referred to as packaging, in which producers attach a substrate (mainly for thermal management), wire the chips, and provide further optical conditioning. Several LED packages thereby can be combined to more powerful LED modules. Finally, *downstream* production refers to the manufacturing of LED applications, often consisting of quite basic assembly operations.

The production of the actual lighting units, especially the technologically intensive field of upstream production, currently is the most lucrative segment. The mostadvanced companies in this segment can also count on additional revenues from licensing IP rights to other producers that may employ their technological solutions.

Although some of the largest LED producers, such as Philips or Osram, are vertically integrated enterprises, the predominant structure of the value chain is a modularized one in which upstream, midstream and downstream companies form separate entities. The following trends can be singled out: the traditional lighting giants Osram, General Electric and Philips-Lumileds emerged as major players because these companies had invested early in technology development and constructed LED production facilities alongside their capacities for conventional lighting. They also held a large share of IP rights for LED technology, which raised the entry barriers for newcomers (NSR 2010: 13). However, specialized LED companies such as the current market leader Nichia from Japan, the US-based company Cree, and the Korean 'latecomers' Samsung and LG, have gained market shares during the 2000s. In addition, Taiwanese companies such as Epistar and Everlight have taken advantage of the profound knowledge of the region's semiconductor producers.

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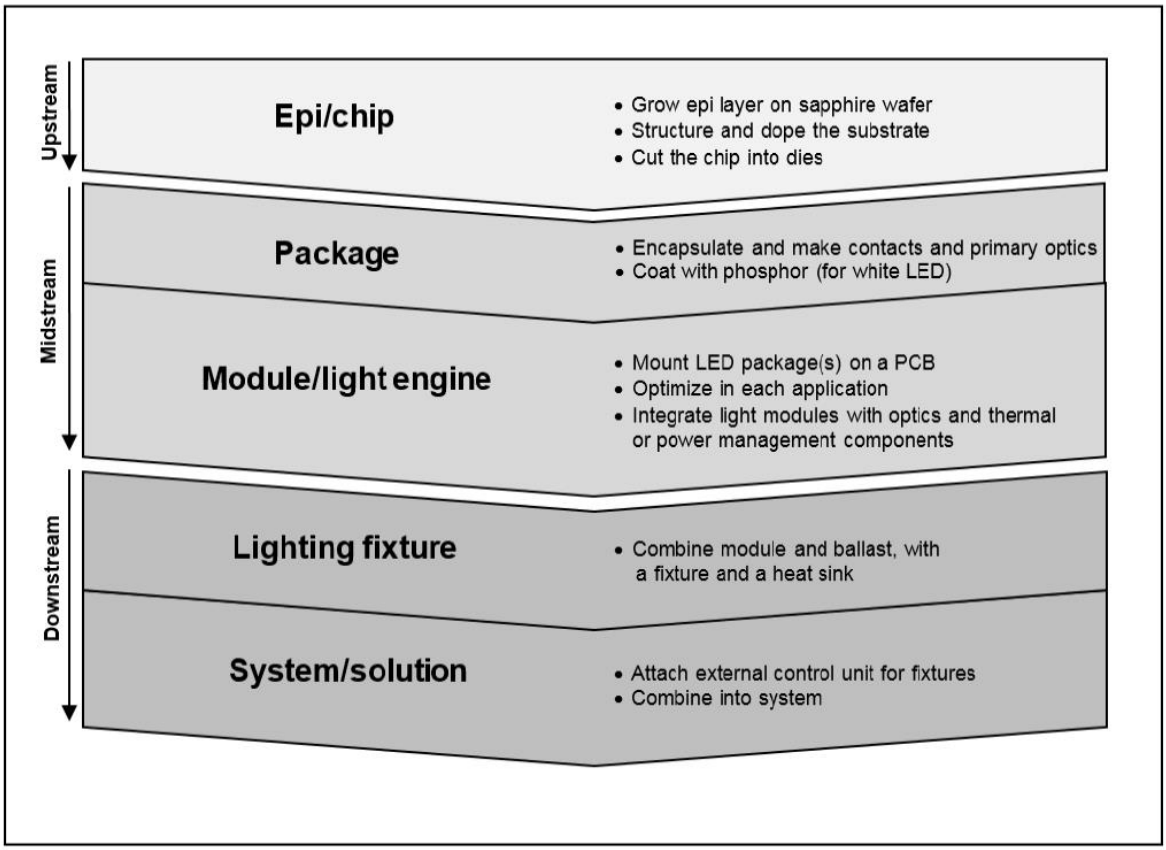
Figure 1: The LED value chain



Source: authors.

Lately, leading Chinese producers such as San'an, Nationstar and HuaLei have gained significantly in importance and are listed in a recent ranking of the world's largest LED producers (see Table 1). Overall, the old oligopolistic structure of the global lighting industry is thus in the process of being broken up through continuous market reshuffling.

Growing importance of the general lighting market

Until 2010, the revenues of the LED industry still constituted a small but growing fraction of the global lighting industry. Initially, the industry took off by supplying backlight modules for mass consumer electronics devices (for example, smartphones). Currently, it is entering a new growth cycle by venturing into general lighting, which is becoming the most important segment of the market.[5] Most manufacturers reoriented their business focus from backlighting to the general lighting market.

In the upstream and midstream segments, this usually necessitates offering products with a higher lighting efficiency, which in turn, increases the pressure for product upgrading. In the downstream segment of LED applications, it often implies functional upgrading by creating own brands, since the general lighting market mostly addresses private end consumers (while other segments such as the market for backlighting modules for mobile phones does not). In China, most LED producers that turn towards the general lighting market modify their business model from one that supplies foreign

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Table 1: Top 30 LED vendors in the world by revenue, 2012–2014 (US$ millions)

		Origin	2012	2013	2014 (estimated)
1	Nichia	Japan	2395	2510	2608
2	Samsung	South Korea	1218	1390	1398
3	OSRAM	Germany	1106	1198	1258
4	LG INNOTEK	South Korea	849	933	908
5	Seoul Semiconductor	South Korea	731	921	1058
6	Cree	USA	757	895	928
7	Everlight	Taiwan	644	832	993
8	Epistar	Taiwan	647	749	1017
9	Liteon	Netherlands	543	674	792
10	Lumileds	Taiwan	568	610	608
11	Lumens	Japan	414	577	708
12	Toyoda Gosei	Japan	660	538	470
13	Sharp	Japan	409	486	508
14	LEXTAR	Taiwan	489	463	499
15	San'an	China	258	360	398
16	Citizen	Japan	380	338	350
17	Kingbright Electronics	Taiwan	240	270	290
18	Unity Opto	Taiwan	255	233	293
19	Optotech	Taiwan	223	215	217
20	Harvatek	Taiwan	127	157	211
21	Genesis	Taiwan	123	132	171
22	Formosa Epitaxy	Taiwan	164	148	165
23	TYNTEK	Taiwan	113	140	225
24	Nationstar	China	106	115	118
25	Bright LED	Taiwan	113	94	83
26	Edison Opto	Taiwan	77	92	119
27	HuaLei Optoelectronic	China	50	85	108
28	Tekcore	Taiwan	55	62	67
29	ELEC-TECH	China	60	62	88
30	HC SemiTek	China	52	51	116

Note: These figures include revenues from wafer production and packaging, except for the case of Samsung and LG Innotek where some revenues from LED module production are included.
Source: (RIC 2014).

brands in buyer-driven value chains towards one that involves becoming a lead firm in its own right. Such companies source from local suppliers and cater to Chinese customers. In other words, we are witnessing the emergence of a domestically centred regional supply chain in the general lighting segment alongside those dominated by foreign companies in which Chinese firms only hold inferior positions. As our sample demonstrates, some companies pursue a dual strategy by continuing to supply products to foreign firms while simultaneously launching their own brands for the Chinese market. As Zhou (2008) observed in the case of Huawei and Lenovo, emerging Chinese brands can benefit from a broad supplier base with sufficient technological capabilities due to technological learning facilitated in production networks with foreign lead firms.

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China's LED sector: massive growth despite technological gaps

These general tendencies set the stage for upgrading the efforts of Chinese LED enterprises. Three circumstances put the Chinese industry in a favourable position. First, China was already a strong production base for lighting products before the advent of LED technology. In 2010, 80 per cent of all energy-saving compact fluorescent lamps were produced in China. Many traditional lighting enterprises thus converged towards LED. In a broader sense, China's recent history of high-tech manufacturing means that there is an increasingly dense and diversified network of IT suppliers (Lüthje et al. 2013: 135–54) coupled with a strong local-government interest in strengthening indigenous innovation (Yang 2014). Second, the domestic market for lighting products is growing particularly fast. In 2011, the Chinese lighting market already had a 15 per cent share of the global market. Until 2020 this volume is expected to rise to about 23 per cent (Lee et al. 2014; McKinsey 2012: 27–9). Third, since the end of the 2000s the Chinese authorities have been giving particular support to the LED industry at central and especially local levels (see the following section).

Under these circumstances, China's LED sector has mushroomed. Output has grown by more than 30 per cent per annum since 2006 and it quintupled between 2007 and 2013 to ¥257.6 billion (that is in excess of US$ 40 billion, see Table 2).

Table 2: Combined output of China's LED lighting industry 2009–2013, (¥ billions)

	2006	2007	2008	2009	2010	2011	2012	2013
Output	35.6	48.3	62.9	82.7	120	156	192	257.6
Growth rates		35.7%	30.2%	31.5%	45.1%	30.0%	23.1%	34.2%

Source: (CSA Research 2013).

Yet, given that production is still strongly concentrated in the technologically less demanding downstream segment, these aggregate figures obscure the relative technological weakness of Chinese producers. In 2013, the yield of downstream companies constituted nearly 80 per cent of the total output of the Chinese LED industry, while that of midstream companies represented 16 per cent and that of upstream companies merely 4 per cent (see Table 3). Although companies need to acquire certain proficiency with regard to optics and heat reduction technologies, downstream production in most cases consists of basic assembly operations. The production of applications such as streetlights mostly involves low-tech production based on manual assembly. Representatives of local industry associations unanimously complained about the low technological capabilities of downstream LED manufacturers (interview data (ID) 1, 4, 5).

In the midstream and upstream segments, until the early 2010s, Chinese companies lagged quite far behind the international leaders technologically, but there has been progress recently (see section below on the domestic market as catalyst for upgrading). As latecomers, they generally failed to match foreign competitors in terms of lighting efficiency, which remains essential for producing first-rate applications and reducing

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costs. Thus, Chinese application producers (including all the downstream companies in our sample) used foreign companies' LED chips for their products until very recently, which implied that companies from abroad remained the main beneficiaries of the Chinese LED boom. Consequently, the backwardness of Chinese companies in the technologically challenging segment of upstream production was considered the weak spot of the Chinese LED industry (ID 2, 3, 5; Liu and Qiu 2010). We now turn to the critical factors that altered this constellation.

Table 3: Output of the LED industry segments in China 2006–2013, (¥ billions)

	2006	2007	2008	2009	2010	2011	2012	2013
Upstream	1.0	1.5	1.9	2.3	5.0	6.5	8.0	10.5
Midstream	14.6	16.8	18.5	20.4	25.0	28.5	32.0	40.3
Downstream	20.0	30.0	42.5	60.0	90.0	121.0	152.0	206.8

Source: (CSA Research 2013).

State-induced upgrading: proactive local policies

Policy measures to support upgrading the LED industry are pursued through central programmes, but more importantly through competing local authorities, each of which defines a variety of means to nurture companies, especially the larger, more advanced ones.

The central government responded to the weaknesses of the LED sector by promoting the development of the upstream segment, namely 'self-sufficiency' with regard to the supply of LED chips (Chu 2010). The twelfth five-year plan listed the following specific targets until 2015 – raise the share of LED products to 30 per cent of the volume of the Chinese lighting market; increase the share of Chinese LED chips in applications produced in China to 70 per cent; establish two to three leading upstream companies; and establish three to five leading downstream companies.

The plan is broken down into and fostered by a number of policies that are implemented mostly at local levels, some of which were put into action after 2008:

- Local governments granted huge *subsidies* to the tune of eight to ten million RMB (roughly half the sales price) to upstream producers for the acquisition of MOCVD reactors, the key equipment for producing LED wafers. Most conspicuously, the Xiamen city government comprehensively supported China's leading upstream producer San'an. These subsidies for local producers led to an investment surge that the central government found increasingly difficult to control. Consequently, Chinese companies were made responsible for 57 per cent of global orders for MOCVD reactors in 2011 and remained the most important market for it in 2013 and 2014 respectively (LEDinside 2013b). The subsidies had the immediate effect of lowering the entry barriers for domestic firms and thus strengthening domestic firms in the strategically important upstream segment, while they also provoked

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severe overcapacities, which, in the end, inadvertently created more competitive firms.

- In 2009, the Ministry of Science and Technology (MOST) issued a comprehensive market creation programme for the public procurement of LED lighting products called '21 CITIES, 10,000 LED LIGHTS'. This system provided funding for LED purchases derived from the projected energy savings by these purchases. Thus, it reduced local government barriers to invest in LED street lighting. However, in 2012 this central plan was outmatched by even more ambitious regulations in Guangdong to replace all conventional lighting with LED technologies by 2014 (Guangdong government 2012). By creating a market for LED products in the field of general lighting through public tenders, the government gave preferential treatment to local producers. This created opportunities for local firms to upgrade functionally through the creation of own brands (see subsection below under the heading 'Functional upgrading: creating brands for domestic consumers').
- A 2011 National Development and Reform Commission (NDRC) plan gradually to eliminate incandescent lighting mirrored comparable programmes in the West and sent a strong signal to local actors. A scheduled ban on conventional lighting supported initiatives for LED market creation and thereby enhanced the associated upgrading effects. Significantly, the government recently decided to end its subsidies for conventional energy-saving lighting technology, thus ensuring that LED companies benefit most from the phase-out of incandescent lighting (LEDinside 2014d).
- Various local measures were introduced to support technological innovation. These included research funding, favourable tax policies, encouraging cooperation between research institutions and enterprises, and funding local technology innovation centres (Guangdong government 2011, 2012). The Guangdong government lay emphasis on the creation of innovation centres to serve as platforms for technology diffusion. On the one hand, these efforts were aimed towards catching up technologically by strengthening basic research in state-funded LED labs and universities. On the other hand, their objective was to strengthen manufacturability through supporting companies with independent research capacities. While the overall effectiveness of these measures for strengthening technological capabilities would deserve a separate investigation, the qualitative data from our sample of six companies, as well as interview data, indicate a significant impact at company level; companies benefited particularly from direct subsidies and from funding through project applications or awards.
- Indigenous LED product standards were deliberately set lower than international ones. This allowed the government to keep the number of technologically immature products in check and created incentives for continuous product upgrading by local firms while maintaining market space for companies that could not yet meet the tougher criteria on international markets (ID 6; Virey and Cohen-Laroque 2013).

Dragons emerging: effects of industry turbulence between 2011 and 2013

As the interviewees unanimously pointed out, subsidies and market creation through investment programmes implemented by local authorities were critical in launching an

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investment frenzy from 2009 onwards. The government programmes were launched amid growth projections for the LED industry that were highly positive and this further encouraged voluminous investments.

This had various effects on industry segments. In the upstream segment, companies took advantage of the MOCVD subsidies and bought reactors in high volumes. Within a few years, Chinese firms rose from marginal positions to world leaders in upstream production. In the downstream segment, procurement programmes led to the installation of hundreds of thousands of LED streetlights in Chinese cities, provided by local producers. LED companies in the Pearl River Delta (PRD) reacted to state-induced demand by launching downstream product lines under their own brand name. This even applied to companies specializing in midstream or upstream production (see subsection on functional upgrading below).

Yet, as in any gold rush, the frenzy soon reached its limits and developed some hazardous side effects. The industry's development was a turbulent process, which depended largely on the activities of competing local actors whom the central government failed to control. From late 2011 onwards, the Chinese (and the global) industry was riddled with severe overcapacities. In the upstream segment, plummeting prices depressed profit margins (LEDinside 2013a). In the midstream and downstream segments, overcapacities equally resulted in declining prices. Many LED companies in the PRD, among them locally well-known enterprises with considerable technological capacities, went bankrupt (ID 6, 7).

The destructive side effects of state intervention in LED production have provoked critical responses from participants in the industry (ID 6, 7). However, as a sales manager of a medium-size LED packaging company put it, 'currently the industry is a mess. There are strong and weak companies all mixed together. The current situation is as if the water washes the sand away so that gold remains at the end' (ID 7). Therefore, the largest firms in particular, such as San'an or Nationstar, could expand their operations significantly. While it is doubtful that this was the authorities' objective, the crisis did indeed have the effect of distributing the gains to the strongest enterprises. The concentration of the LED sector and its biggest manufacturers thus complements the policy aim of creating competitive enterprises.

The large amount of overinvestment actually turned out to be the price paid for the fundamental progress of the LED industry leaders, for many of the smaller manufacturers withdrew from the LED sector altogether and sold their MOCVD capacities to larger firms. In other words, instead of intervening directly, the state institutions relied on a market-driven process of 'Schumpeterian' creative destruction. Overinvestment thus fostered a few 'dragons', especially in the upstream and midstream segment. What role did the domestic market structure play in this constellation?

The domestic market as catalyst for upgrading

Strong growth of domestic demand for LED products allowed the share of LED products in the growing Chinese general lighting market to jump from 3.3 per cent

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(2012) to 8.9 per cent (2013). LED products have become a viable choice for private consumers on a mass scale.

Domestic market growth, partly driven by local public investment, facilitated industrial upgrading in various industry segments. Like in other product markets (Brandt and Thun 2010), where particularly strong demand exists for medium-range products sold at comparably low prices, Chinese LED vendors are well adapted to address this demand. They found sufficient space to expand economically despite an ongoing technological lag vis-à-vis the most technologically advanced LED producers abroad.

Product upgrading: success of Chinese LED upstream producers

This development is particularly visible in the upstream segment, especially with respect to San'an. After investing aggressively in MOCVD equipment in recent years, in 2013 the company captured a 29 per cent share of the domestic upstream market (LEDinside 2014c). While much LED equipment in China was still lying idle because of overcapacities, in 2014 San'an announced the acquisition of another 100 MOCVD reactors, thereby doubling its capacities (LEDinside 2014b). By the end of 2014, the company was expected to have the largest capacity for the much used 'two-inch GaN' wafer category, in fact more than one-tenth of global capacities (EE Times 2013). San'an was also investing heavily in foreign and domestic business partnerships to compensate for its lack of key patents and to ease supplier cooperation on the mainland; among these is a joint venture with the Korean upstream producer Seoul Semiconductors and a supply agreement with Nationstar, which was then the second biggest midstream LED company in China.

Overall, the tables have begun to turn because the Chinese industry significantly reduced its dependence on foreign component suppliers; in other words, domestic Chinese LED chips were accepted as a viable alternative to imported ones. The self-sufficiency rate in the upstream segment of LED chips – the share of domestically produced chips (measured in production volumes) – rose from about 50 per cent in 2008 to over 75 per cent in 2013 (see Table 4).[6] Due to the success of the upstream industry, one of the main goals of the central government laid out in 2011, self-sufficiency in terms of LED chips, had already been achieved by 2013.

Table 4: Share of domestically produced LED chips, 2012–13 (%)

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Share	0	5	20	28	44	46	49	52	60	68	72	75

Source: (CSA Research 2013).

Chinese LED upstream producers were gaining market shares despite an ongoing technological lag vis-à-vis foreign competitors. Chinese companies, including San'an, lack access to key patents and the production expertise that would enable them to

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approach the global technological frontier and Chinese chips are still unable to match the lighting efficiency of their foreign competitors. However, Chinese producers excel in the home market for mid-power components in which demand is strongest. San'an, for instance, is especially capable of ramping up production in this field quickly and therefore benefiting from economies of scale. Chinese firms were able to catch up with Taiwanese competitors in medium quality segments through technological improvements; in addition, because prices of domestic Chinese chips have been falling more rapidly than those of their Taiwanese competitors, they have recently gained additional market shares (LEDinside 2014a, 2014c). Moreover, the very overcapacities that threatened the existence of numerous companies now give the industry leaders a competitive advantage. Equipment that had been used only at half capacity can now be used to satisfy additional demand and large producers are thus able to ramp up capacities more quickly and to sell products more cheaply than their competitors (Bradsher 2014).

Functional upgrading: creating brands for domestic consumers

The growth of the domestic market has shaped the production models of firms across all segments of the LED value chain. Despite the turbulences, the market for LED applications grew massively between 2006 and 2013. Companies across the value chain, reacted to this trend by offering products adapted to the domestic market.

Particularly pronounced is the tendency for companies to create their own consumer brands. From our sample of six companies, all but one offers products for LED lighting end markets, such as streetlights or home lighting applications, under their own brand name. Some examples illustrate how companies incorporate domestic market orientation into their business strategies and how this affects their efforts at upgrading:

- In 2010, one of China's largest midstream companies to supply large electronics companies with LED packages for backlighting and general lighting applications (PACKAGESTAR)[7] constructed a factory for LED applications, that is downstream production. In 2011, these own brand products already constituted 11 per cent of output, and this later rose significantly. The domestic market thereby triggered a functional upgrading of the firm, which strives to raise its share of value added by expanding into the downstream business.
- MULTIAPP, a downstream company that formerly specialized in backlighting modules as supply products for consumer electronics, also engaged in functional upgrading by adding a product line for general lighting products to its portfolio, which are sold under its own brand name. This implied a major shift in its production of own brand products to around 70 per cent of company revenues.
- ARCHIAPP, a supplier of entertainment lighting, added a line of own brand products for the domestic market to its portfolio. Although formerly revenues were primarily realized by international sales of supply products, the domestic market share recently expanded to roughly 25 per cent. Notably, the company does not plan

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to advance towards own brand production on international markets where it would be confronted with heavy competition with its own customers. Functional upgrading towards brand building is thus limited to domestic market sales.

The degree to which companies embarked on strategies of brand production for the domestic market varied in the observed cases. However, the addition of LED applications to the companies' portfolios in each case supported their development by creating a substantial field of income and by stimulating the acquisition of new capabilities in design and marketing (functional upgrading). By providing a leeway for the expansion of local firms, the domestic market fostered Chinese firms and their functional diversification.

Domestic market, FDI and technology sourcing

With a rising share of the global LED market and forecasts for fast growth, the Chinese market is attracting foreign direct investment (FDI). As Osram (2014) declared when opening its large-scale LED midstream company in Wuxi: 'With this step, we're … boosting our presence in the world's largest single lighting market. … With the new LED assembly in Wuxi, Osram will be in an even better position to address that growth.' The same logic of 'producing where you sell' (Herrigel 2015) led to substantial FDI by Cree, SemiLEDs and Epistar – all facilitated by local state actors interested in raising the technological capabilities of Chinese firms (Yang 2015: 671–3). Some of the investments were placed as mergers or acquisitions, for example the Chinese midstream company Nationstar cooperated with SemiLEDs from Taiwan, which was a strategic move by Nationstar to enhance the company's technological capabilities to access the upstream market. San'an also engaged in similar strategic cooperation bybuying 19.9 per cent of the Taiwanese upstream company Formosa Epitaxy's shares. In this way, Chinese LED firms successfully engage in global technology sourcing (Ernst 2014) and such acquisitions are largely interpreted as a way of allowing Chinese companies to enter technologically challenging industry segments (ID 8). Demand for LED products facilitates such cooperation since foreign companies are eager to access the Chinese markets and to 'join forces' with domestic companies.

Conclusion

Our investigation reveals a pronounced dynamic of industrial upgrading in the Chinese LED industry, indicated by the thriving general economic performance of the sector on the one hand, and rising competitiveness among domestic companies in technology-intensive industry segments on the other. So far, the industry has experienced a technological leap that puts the leading producers in a favourable position to gain from a steadily growing market. San'an, in particular, has managed to acquire the biggest market share on the domestic market and is emerging as the largest production capacity for two-inch GaN LED wafers worldwide. While the relative technological gap vis-à-vis foreign producers persists in export markets, in the domestic market the leading Chinese companies are sufficiently close to the technological standards of their

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Taiwanese competitors to gain a higher market share. Other domestic brands, mainly a broad range of SMEs with lower technological capabilities were, with the backing of state-driven demand, still able to generate revenues but face an uncertain future in the face of an increasingly competitive market.

Our results also provide ample material to illustrate how local state support under the condition of intra-state competition facilitates industrial upgrading. First, funding investment (particularly subsidies for the acquisition of MOCVD reactors) triggered an investment spree that benefited China's most advanced companies. Second, market creation through the '21 CITIES, 10,000 LIGHTS' programme constituted an outlet for LED applications that were not yet ripe for mass consumer markets and provided producers with incentives to offer general lighting products under own brand names. Finally, local financial support for technological innovation strengthened the innovative capabilities of firms and facilitated technology diffusion. To be sure, aspects of these policies may be characterized as dysfunctional and irrational compared with stylized models of the developmental state (Yeung 2014: 92). However, they contributed to the growth of the LED sector, even if this did not always occur as originally intended.

The growth of the domestic market – partially also a product of state-induced market creation – provided ample space for the development of companies, despite an ongoing technological lag. This is particularly visible in the upstream segment where Chinese producers gained a strong market position through their ability to supply mid-quality products at low prices. In this respect, the LED industry matches the experiences of other industrial sectors in which the Chinese domestic market proved to be decisive for upgrading (Brandt and Thun 2010; Herrigel et al. 2013). Moreover, domestic market growth spurred the development of Chinese brands for LED applications, an opportunity taken by firms across all segments and resulting in domestically centred value chains controlled by Chinese firms. In addition, the growth of the domestic market also attracted FDI from technologically advanced enterprises with possible beneficial effects on technology transfer (Yang 2015), but the extent to which this happened lies beyond the scope of this study.

In sum, the complementary effects of local state support and an expanding domestic market provided favourable conditions for industrial upgrading. It seems reasonable to assume that comparable progress would have been unlikely without public support for the investments and sales that are instrumental in expanding business in this capital- and knowledge-intensive sector. Similarly, it would have been more difficult to challenge the dominance of foreign producers had Chinese companies relied mainly on an export strategy without being able to build on advantages in mid-quality production for home markets. Our article thus provides evidence of the pivotal role of local industrial policies and growth potentials on the domestic market that foster the emergence of domestically centred regional value chains with lower entry barriers for local firms. These do not constitute an alternative to technology transfer in world market-centred value chains, but flourish by taking advantage of the capabilities that local suppliers acquired in the course of world market integration (as the heavily internationalized Chinese lighting industry so vividly demonstrates). In this sense, domestically centred value chains do not imply a retreat behind national borders, for technology transfer across borders continues to be

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an important factor for upgrading – be it through innovation networks (Ernst 2009) or the 'strategic coupling' of foreign and domestic firms (Yang 2014). Moreover, brand building on the domestic market can be a stepping-stone to success in export markets as the cases of Huawei and Lenovo (Zhou 2008) demonstrate.

Does the experience of the Chinese LED industry, then, indicate the advent of a new development paradigm after the Washington Consensus? In this regard, it needs to be acknowledged that upgrading trajectories in China vary considerably between industrial sectors. The extraordinary development of the LED industry, based also on the paradoxical effect of an over-subsidization of the sector, appears to be unique and difficult to replicate. Correspondingly, Ernst (2014) underlines the ineffectiveness of traditional industrial policies based on the subsidization of firms in the semiconductor industry. However, we assume that both ingredients – proactive local state support and strong domestic demand – shape the upgrading experiences across industries in China to a substantial extent. A nuanced understanding of their development therefore needs to consider these factors rather than to focus purely on a framework of industrial upgrading in (export-based) production networks. More comparative cross-sector analyses of industries in China are needed to identify the specific mix of state/market and export/domestic market relationships, as well as the determinants that affect industrial upgrading in each case.

Another issue open to debate is the specificity of China. Without doubt, China differs from other countries with regard to its institutional and economic structure and the extraordinary scale of its manufacturing capacities and markets (Henderson and Nadvi 2011; Henderson et al. 2013; ten Brink 2013). Yet, first, the seismographic shifts in global demand are not limited to China. The 'middle markets' of relatively affluent consumers are playing an increasingly important role, especially in the largest emerging economies, and are creating a growing demand for mid-quality products in segments where domestic firms are becoming more competitive. This may support a 'reintegration from below' between local markets and industrial regions in large emerging economies. These factors lie behind the regionalization of value chains (Gereffi 2014), which in turn may, because of tighter feedback loops between customers and firms, enhance upgrading opportunities. Second, while the transnationalization of production limits the potential for industrial policies in small states, large emerging economies such as Brazil or India may be able to emulate China's path (Nölke et al. 2015). This accounts for public policies such as market creation, but also for the other elements of proactive (local) industrial procedures that remain the prerogative of large territorial states. Nonetheless, whether other large emerging economies can match the Chinese experience in this respect remains an open question.

Despite the specificity of the Chinese case and the indicated uncertainties about its generalization, we hold that the emergence of large consumer markets in developing countries, combined with the capacities of state authorities to regulate markets and stimulate industrial development, constitute important conditions for industrial upgrading in a 'post-Washington Consensus world', under circumstances yet to be investigated. These 'qualitative implications' of shifting end markets thus deserve more attention in empirical enquiry and need to be incorporated better into theoretical

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frameworks that seek to understand industrial upgrading in a geographically dispersed economy.

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Notes

1. In our sample, we chose the chairs of leading industry associations in the Pearl River Delta, management staff of local companies from each sub-segment of the industry, and academic researchers. The semi-structured qualitative interviews focused on the general development of the industry, enterprise strategies and paths of industrial upgrading, the precise manner of state support and the forms of workforce deployment. The data were evaluated according to qualitative content analysis.
2. Subsequently, the terms 'GVC' and 'GPN' refer to the respective theoretical frameworks, whereas we use the terms 'production network' or 'value chain' when we refer to the empirical phenomenon.
3. There are certain similarities in other large emerging economies. See Kadarusman and Nadvi (2013) on Indonesia and Navas-Alemán (2011) on Brazil.
4. This categorization is derived from the understanding of Chinese actors, which is slightly different from other analyses of the global industry in which the process of packaging/encapsulation is included in the category of upstream production (Li and Qiu 2010; McKinsey 2012).
5. The first growth cycle was launched by LEDs for small display backlighting, and the second by LEDs for large display backlighting.
6. The market share of Chinese companies in production volumes is higher than their market share in production values. This reflects that the average price per chip is lower for Chinese companies and that they are supplying products for lower market segments.
7. All company names are anonymized.

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3. Sales manager, SMARTPACKAGE, Shenzhen, 19 November 2010.
4. Chairman, Foshan Lighting Association, Foshan, 3 December 2010.
5. General secretary, Guangdong Solid-State Lighting Association, Foshan, 10 December 2010.
6. General secretary, Guangdong Solid-State Lighting Association, Guangzhou, 10 November 2011.
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