OPTIONS FOR ENERGY EFFICIENCY GAINS AMONG CHINESE STEEL ENTERPRISES

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ABSTRACT

Hard production capacity expansions among Chinese steel enterprises were the characteristic go-to strategy for ensuring healthy margins and market share in the last decade. Chinese authorities are under increasing public pressure to crack down on the nation's big polluters. As China enters a less resource-hungry phase of growth and world steel demand in the developing world is stagnant, focusing on energy efficiency improvements among existing capacities is key to remaining competitive in today's global steel industry. This paper will provide succinct policy recommendations for Chinese (economic) policy makers to incentivize improvements in energy efficiency throughout the entire production process by a) analyzing the historic development of the steel industry, b) providing a glimpse into future developments, c) drawing parallels between different countries and scenarios. The paper recognizes that current incentive schemes for efficiency gains are inadequate and formulates five policy recommendations.

ACKNOWLEDGEMENTS

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Table of Contents

Table of Figures

INTRODUCTION

China now produces close to 50% of the world's steel. Much of this capacity was built up in response to a decade of double-digit average growth figures, extensive government support and preferential tax treatment for heavy industry. Steel consumption and economic growth often go hand-in-hand and follow the same trajectory, especially in newly industrialized countries.[1] These countries have typically surpassed phases of development where the agrarian sector is overrepresented in their economies, but did not yet arrive at a stage where the service sector is the dominant source of growth and contributor to gross domestic product. This leaves industry and manufacturing as the primary driver of economic output, thereby expanding demand for steel.[2] Given the strategic nature of steel industry investments as well as long lead-times in construction, there is a distinct danger of the economy losing its momentum or structurally changing with excess production capacity in place or still in construction. Renowned global mining correspondent John W. at Wall Street Journal has succinctly summarized the current situation:

> [In 2012], steel mills around the world have a production capacity of 1.8 billion tons but will take orders for only 1.5 billion tons. And instead of consolidating and becoming more efficient, the industry is building still more capacity (Miller, 2012).

Slow economic recovery in developed markets, uneven growth in world economic output [3] and lackluster growth figures in China for 2012 have caused worldwide economic performance to erode under the steel capacity glut created during the boom years in the 2000s (SBB, 2013n). It is estimated that China has a growing 200 million metric tons per year excess production capacity, or 13% of forecasted global steeloutput in 2013. Global steel production capacity utilization ratioshave averaged at 78% percent since 2008.[4] It remains debatable why this excess capacity is

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[1] World economic growth and global steel output growth show over 95% correlation between 2003 and 2011.
[2] Even among the BRIC (Brazil, Russia, India and China), the size of China's industrial sector is more than 13% above the BRIC-average, as seen in Appendix 1.
[3] The IMF has forecasted 3.3% global growth in 2013, claiming that "we live in a three-speed economic world" where fast growth is concentrated around developing Asia, medium growth in the United States and Japan, while slow growth is to be expected in the majority of European nations.
[4] Defined as $\frac{\textit{apparent usage of installed steel production capacity}}{\textit{maximum theoretical production capacity}}$

still being built up around the globe, with China at its forefront. The majority of recent steel production expansion projects have taken place in developing or newly industrialized countries, whereas developed countries have stayed on modest steel output growth trajectories and even output declines in recent years. One prominent explanation is that state support of the industry in forms of subsidization and preferential tax treatment in less developed countries provides incentives and creates artificial demand for capacity expansions.

Excess capacity in China is posing serious problems to local, central government politicians and producers alike. Production overcapacity has a wide range of problems associated with it such as heavy pollution, a fragmented industry structure, lack of research and development due to producer "margin squeeze" (SBB, 2013b). China's capacity utilization is forecasted to stand at approximately 75% throughout 2013, meaning that a quarter of production capability will be idled during the course of this year. In general, 85% capacity utilization is considered necessary for profitability.

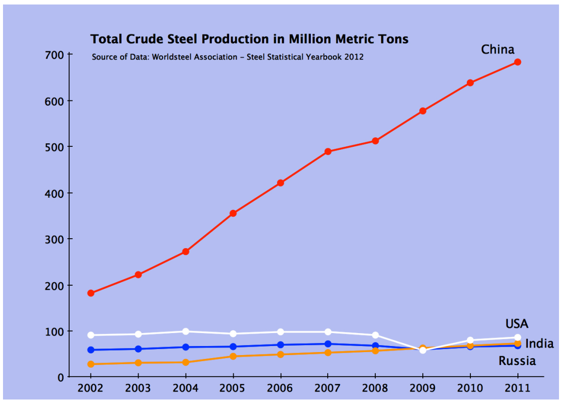


Figure 1 Near-exponential growth of Chinese crude steel output.

Chinese, Foreign experts as well as Chinese policymakers agree that raising efficiency among the existing capacities is the way forward in establishing a healthy industry structure, where supply meets demand. Lakshmi Mittal, CEO of world's largest steel producer ArcelorMittal sees its strategy " … to focus production on our more competitive assets are beginning to yield results" (Fontanella-Khan, 2013). Overall efficiency increases allow for high-volume, bulk production to be phased out by qualitatively more competitive products. This gives producers access to higher end markets as well as more lucrative business with adequate producer margins.

There is ample previous research on energy efficiency in the steel industry, which, however, agrees that there are no universal prescriptions for improvement. Every country has its own set of deficiencies and every market environment provides new challenges for the industry. Another branch of related research is centered around technical, amount of energy usage per unit of output calculations, which pit world best practices against individual countries and provide technical improvement advice centered around the steel production process itself. This paper assumes that steel producers will incorporate technical efficiency improvements in their production process through research and development or acquisitions from foreign, technologically better developed producers. A powerful assumption, but necessary if I want to address the target audience: Chinese policymakers. This thesis will analyze the Chinese and global steel industry, build on previous, overly technical research with the aim of giving policymakers a reasonable insight into the industry and finally, to present them with a handful of policy options to address the pressing issue of the need for energy efficiency gains, primarily to address the capacity glut.

A country-wide problem can only be adequately tackled by the higher echelons of leadership, who are able to incentivize and enact structural changes in the economy. Leaders will not be interested in the steel production process itself, but in what policies they can enact to improve an industry that held 8.9% of the value of all fixed-assets across all industrial sectors combined, has accounted for 7.8% of revenue in the entire industrial system, was the 8th most important major export product and was employing around 3.5 million people in China, in 2010 (Changfu, 2012).

CHAPTER 1 – THE BASICS

This chapter aims to familiarize the reader with the basic knowledge about energy efficiency, the limitations of this work and provide a quick review of Chinese efforts at improving energy efficiency with focus on the steel industry.

1.1 On energy efficiency

Before narrowing down the research to China, this chapter will briefly examine energy efficiency indicators commonly used in the steel industry, as well as shed light on the less technical approach I have chosen for this paper to look at aggregate energy efficiency. Energy efficiency is a very broad term that can either be understood in a microeconomic context, an industry or the economy as a whole. For example the development process that goes into reducing the ratio of energy input per unit of output in an enterprise is a microeconomic energy efficiency endeavor. Forcing large polluters to install filtration systems to reduce an industry's aggregate carbon footprint would be a more comprehensive approach to energy efficiency, which, at this level is commonly motivated by environmental concerns. Factors affecting energy efficiency in the entire economy are broad. According to market leader in high-performance materials, Saint-Gobain, "within the European Union such vast quantities of energy are being lost through roofs and walls alone that Europe's entire Kyoto commitment[5] could be achieved through improving insulation standards" (isover.com, 2013). Improving insulation standards is a policy option that will interest political decision makers, as it requires adjustments to parameters they can influence and which have a significant impact. This is the measure of energy efficiency this paper has chosen for three reasons: (1) the Lawrence Berkeley National Laboratory has extensive microeconomic energy efficiency research work regarding the Chinese steel industry, which is further disseminated in this thesis, (2) the impetus for this paper is a structural problem in the Chinese steel industry,

[5] The EU's Kyoto commitment: for 2020 emissions have to be cut 20% below 1990 levels; by 2050, this percentage should stand around 80-95% (Europa.eu, 2013)

which requires structural adjustments, (3) it addresses policymakers, who need aggregated, economy-wide and disseminated information.

Because we are talking about the steel industry, it is important to understand efficiency analyses and indicators on which this study is built.

As with many industrial production processes, the principal indicator for energy efficiency in the steel industry is amount of energy used per unit of output. The three main units of measurement are Gigajoule/ton (Gj/t), kilogram of coal equivalent (kgce/t, commonly used in China) or metric tons of carbon equivalent (mtce).

Kgce/t benchmarks the energy generated by burning one kilogram of coal. Alternatively, tons of coal equivalent (TCE) is also used.[6]

Gj/ton is the more convenient and wide spread indicator, as it allows for normalization of different energy carriers into one measure. Natural Resources Canada provides a utility, which can compute GJ/t equivalents across industry sectors, using different sources of energy (National Resources Canada, 2013b). Working with different multipliers can convert the energy released by burning one liter of propane, one cubic meter of natural gas and even one kilogram of wood into gigajoules.[7] "…A gigajoule of electricity will keep a 60-watt bulb continuously lit for six months" (Natural Resources Canada, 2013a). After calculating gigajoules for the given energy carrier, you complete the expression by dividing the figure according to the usual weight measurement of the output you are interested in. One would use tons for heavier industry output and kilograms for lighter units of output. Steel production energy intensity, production volume as well as the standard commercial sales quantity is measured using metric tons.[8]

Gigajoules per ton conversion allows for another common practice in the industry: cross-country and cross-industry benchmarking as well as comparison against "world best practices."

[6] 1 TCE =29.39 GJ
[7] 1 gigajoule = energy released by burning 55.6 kilograms of wood (for estimation purposes only).
1 gigajoule = energy released by burning 26.1 m^3 of natural gas.
1 gigajoule = energy released by burning 39.5 liters of propane.
[8] In the United States short tons are still frequently used. 1 short ton (st) = 907.2kg.

Gigajoules per ton can establish comparisons irrespective of the source of energy used to power the steel mill. Therefore, this indicator allows all effects to be controlled for.

The Ernest Orlando Lawrence Berkeley National Laboratory has released a study where it has listed world best practices in certain industry sectors. Throughout all the examined industries, GJ is used in combination with the usual measure of output in the given industry, for example tons or kilograms (Worrell, Price, Neelis et al., 2008). In related research, technical advice is given by industry experts to approach world best practices in selected industries in China and India.

The dissemination of energy efficiency can go further: there are multiple stages in the steel production process (also called adding value, as many of the intermediate products are suited for both sale and as input for further value-adding), as well as different technologies for production. GJ/t is used here as well to isolate the energy efficiency discrepancies between different stages of production.

Furthermore, there is often a distinction between final energy and primary energy use. Here, the former describes the energy used in the steel mill, while the latter adds the energy that was used in producing the electricity to run the steel mill. Appendix 7 shows that China continues to rely heavily on the often inefficient and polluting burning of coal for energy. In such cases, deviations for primary and final energy use can in fact be large, as steel mills rely on electricity produced by burning coal in the less developed, central provinces of China.

		Unit	GJ/t	kgce/t
Iron and Steel				
	Blast Furnace – Basic Oxygen Furnace – Thin Slab Casting	t steel	14.8	504.5
	Smelt Reduction – Basic Oxygen Furnace – Thin Slab Casting	t steel	17.8	606.4
	Direct Reduced Iron – Electric Arc Furnace – Thin Slab Casting	t steel	16.9	576.2
	Scrap - Electric Arc Furnace – Thin Slab Casting	t steel	2.6	87.5

Figure 2 World best practice final energy usage in selected production procedures.

		Blast Furnace – Basic Oxygen Furnace		Smelt Reduction-Basic Oxygen Furnace		Direct Reduced Iron – Electric Arc Furnace		Scrap - Electric Arc Furnace	
		GJ/t	kgce/t	GJ/t	kgce/t	GJ/t	kgce/t	GJ/t	kgce/t
Material Preparation	Sintering	1.9	65.2			1.9	65.2		
	Pelletizing			0.6	19.0	0.6	19.0		
	Coking	0.8	28.6						
Ironmaking	Blast Furnace	12.2	414.9						
	Smelt Reduction			17.3	591.6				
	Direct Reduced Iron					11.7	399.6		
Steelmaking	Basic Oxygen Furnace	-0.4	-15.4	-0.4	-15.4				
	Electric Arc Furnace					2.5	85.6	2.4	80.6
	Refining	0.1	4.3	0.1	4.3				
Casting and Rolling	Continuous Casting	0.1	2.0	0.1	2.0	0.1	2.0	0.1	2.0
	Hot Rolling	1.8	62.5	1.8	62.5	1.8	62.5	1.8	62.5
Sub-Total		**16.5**	**562.2**	**19.5**	**664.0**	**18.6**	**633.9**	**4.3**	**145.1**
Cold Rolling and Finishing	Cold Rolling	0.4	13.7	0.4	13.7				
	Finishing	1.1	38.1	1.1	38.1				
Total		**18.0**	**613.9**	**21.0**	**715.8**	**18.6**	**633.9**	**4.3**	**145.1**
Alternative: Casting and Rolling	Replace Continuous Casting and Rolling with Thin Slab Casting	0.2	6.9	0.2	6.9	0.2	6.9	0.2	6.9
Alternative Total		**14.8**	**504.5**	**17.8**	**606.4**	**16.9**	**576.2**	**2.6**	**87.5**

Figure 3 A more thorough breakdown of individual stages of production according to production process. Source: (Worrell, Price, Neelis et al., 2008)

Figure 2 is a division of energy intensity in different production configurations. Figure 3 contains a more detailed breakdown of the entire production process. These charts are of high informational value to industry professionals and business decision-makers. They will compare these charts to their own indicators and consider which technologies they have to acquire to approach these values. The possibilities for energy efficiency dissemination are endless. Just within the steel industry regional, logistic, technological, energy-related and size-related factors have shown to have impact even on regional-level disparities between steel producers (Xu, 2011). Data suggests that Chinese producers are in fact rapidly becoming more efficient. Rapid efficiency increases are observable across the board both for industry (e.g. Figure 4) and power generation (e.g. Appendix 9).

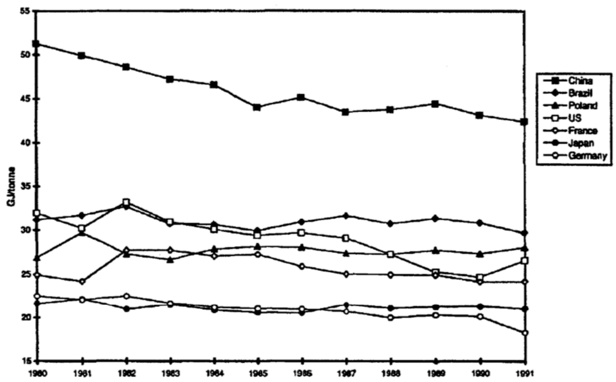


Figure 4 Energy Consumption for iron and steel production, 1980-1991. (Source: Xu, 2011)

Accordingly, I have assumed that plant managers will incorporate technical improvements to foster efficiency increases due to market pressures and the possibilities for rent seeking as long as they maintain an edge over the competition.

1.2 Energy efficiency in China as state policy

Although China has surpassed many developed countries across multiple indicators ranging from gross domestic product and implementation of clean energy solutions, to the number of Ph.D.'s produced annually, it still considers itself "the largest developing country in the world," according to Hu Jintao, speaking at the 90th anniversary of the Communist Party in China in mid-2011.

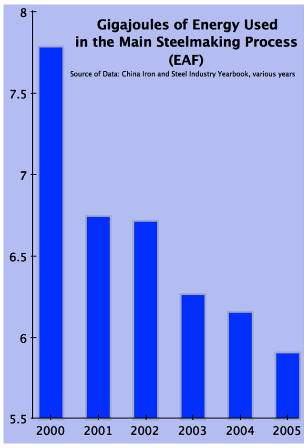


Figure 5 Energy efficiency gains in the EAF production process, 2000-2005

This ambiguity is reflected in its energy efficiency efforts as well. In past negotiations in climate panels, most notably the Kyoto Protocol, the government emphasized its dismay towards holding developing countries to similar standards in energy usage reductions and efficiency targets, claiming that it is "unfair to expect impoverished people in … developing countries to cut back on energy consumption, which is not even sufficient to meet their basic living conditions" (Worldwatch, 2013).

The first meaningful inclusion of energy efficiency targets to state-level policy happened in the 11th Five-Year Plan (2006-2010), where the government committed itself to a 20% energy-savings target. The results were internationally recognized as a fast pace that "has rarely been achieved by the rest of the world" (Mastny, 2010, p. 5).

A document that is fairly similar to the goals of this thesis is the China Medium and Long Term Energy Conservation Plan, produced by the National Development and Reform Commissionin 2004.[9] The document envisions three stages of development: 2005, 2010 and 2020. In these periods, it specifies ambitious goals for the aggregate economy, for example:

> Energy consumption indicators per unit of major products (amount of output): By 2010, China's products as a whole are expected to reach or approach the advanced international level of the early 1990s in terms of the indicators, of which large and medium sized enterprises are expected to reach the advanced international level at the beginning of the 21st century; and by 2020 China is expected to reach or approach the international advanced level (NDRC, 2004, p. 9).

[9]The NDRC is considered the authoritative macroeconomic planning agency within the Chinese economy.

The document then proceeds to outline the major consumers of energy within the economy while highlighting environmental concerns related to the nation's principal reliance on coal. New technology and use of advanced production processes is seen as the major driver of efficiency growth. The main body of the document is divided according to energy consumption per unit of output across eight major industries: electric power, iron & steel, nonferrous metals, petrochemical, building material, chemical, light industry and textile industries. In 2005, these industries consumed around 40% more than comparable sectors in advanced economies (NDRC, 2004).

According to the paper, technological improvements are the backbone of efficiency gains within the steel industry as well. These contain production procedures that this thesis assumes to be in the purview of industrial professionals rather than political decision-makers. A Nippon Steel and Sumitomo Metal corp (NSSMC) spokesman has recently commented that the company has been more successful in the sale of coke dry quenching (CDQ) systems in China, compared to India (SBB, 2013g).[10] Systems to recapture and reuse excess gases and heat from the iron-making process are also mentioned in the NDRC document. These systems are also increasingly being used among Chinese producers. Xinyu Iron and Steel has reported that it was able to save USD11.7million on power charges after installing Top-Pressure Recover Turbine Plants (TRT) in 2009 (SBB, 2009b).[11] In the same year, Wuhan Iron and Steel, China's third and the world's 5th largest steel producer, has invested USD16million to install additional CDQ facilities with the goal of equipping its flagship mill in the city of Wuhan with a total of five

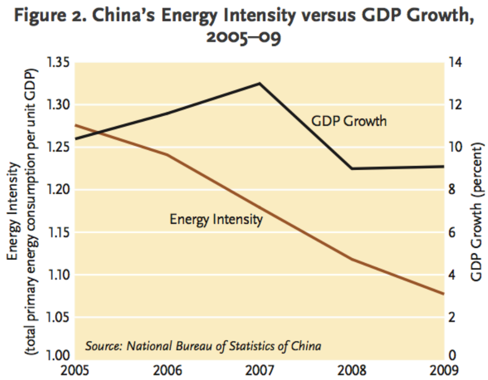


Figure 6 China's energy intensity and GDP growth, 2005-2009. Source: (Mastny, 2010)

[10]NSSMC is a Japanese producer of high-quality steels. The company is the world's 6th largest steel producer by volume. CDQ refers to Coke Dry Quenching. It is essentially a closed-system procedure of capturing excess heat to reduce harmful emissions during the transformation of coal into metallurgical coke, which is most commonly used in steel production. NSSMC is considered a market leader in CDQ development and installation.

[11] TRT systems are similarly used to capture excess heat and gases during the steelmaking process itself.

CDQ plants. The company estimated that in 2009, 40,000 tons of coal to be consumed for energy purposes, was saved by the endogenous electricity produced by its CDQ system (SBB, 2009a).

There is ample evidence to believe that there are competitive forces between steel producers, forcing them to adopt technological changes, giving further merit to this paper's assumption, namely, that efficiency increases of technical (technological) nature will be implemented by producers.

A Worldwatch report on renewable energy and energy efficiency points to the many aspects in which China is a major contributor to global pollution concerns, yet it performs exceptionally well across all improvement indicators and is the world leader in wind-power utilization and solar cell production for commercial use, among others (Mastny, 2010). Economy-wide efforts for energy efficiency are apparent, as seen in Figure 6. The first fall in energy consumption per unit of GDP was registered in 2006, the year the 11th 5YP went into effect.

1.3 Research methodology, contribution and limitations

This thesis combines international practices, conclusions based on quantitative data and historical experience to offer policy recommendations to Chinese policymakers to tackle problems with the Chinese steel industry within the context of the issues they are facing – mounting public pressure due to environmental degradation, serious steel production overcapacity problems, and industry-wide loss of competitiveness vis-à-vis other emerging countries. This thesis fits well into the profile of the Economic Policy in Global Markets program, as it combines economic analysis and data evaluation as well as a thorough consideration of past policy choices of other countries for me to transform into recommendations for senior political leadership. Not to mention the subject covers a commodities market that is of vital importance and is truly global – steel.

The inquisitive reader might wonder what the value-added of this thesis is, in light of such prestigious research institutions as the Lawrence Berkeley National Laboratory (hereafter referred to as LBNL) already engaged in thorough research regarding the topic of energy efficiency. It is my observation that a significant amount of work that the China Energy Group of the LBNL publishes is rather technical. There is no transmission mechanism that would put the research results into cogent policy options for policy makers to address. From this it follows that this paper will address overall energy efficiency across the entire Chinese steel industry as opposed to advice offering technical improvements during the production process, which again, is not the domain of policymakers – the target audience of this paper. For example, Hasanbeigi, Chunxia et al. (2011) find that after controlling for selected disparities,

> … the final energy intensity of the Chinese steel industry is 23.11 GJ/t crude steel while that of the U.S. steel industry is 14.90 GJ/t crude steel (36% lower) and the primary energy intensity of the Chinese steel industry is 26.3 GJ/t crude steel while that of the U.S. steel industry is 19.98 GJ/t crude steel (24% lower). (p. 64)

While informatively this conclusion is valuable, it still has to go through stages of evaluation to be fit for policy recommendations. In a related research paper, Worrell, Blinde et al. (2010), under the auspices of the LBNL, offer micro-level energy and cost efficiency improvement opportunities "for energy and plant managers." Hasanbeigi's team has also devised company-level financial analysis tools for energy conservation projects. Similarly, an advanced Microsoft Excel-based computational utility was devised to compute energy efficiency and greenhouse gas emissions for a given company (LBNL & AISI, 2010). Overall the evidence is overwhelming that the China Energy Group of the LBNL, considered to be the authoritative research agency in Chinese energy efficiency in selected industries, has chosen microeconomic efficiency analyses targeted at industry professionals and plant managers as its main research portfolio.

One might also wonder whether the overrepresentation of non-Chinese literature could impact the quality of the thesis. First, the LBNL China Energy Databook (2008) provides extensive numerical information and data on various energy indicators in China, broken down into industries, energy carriers and provinces. The LBNL China Energy Group comprises a very diverse international team also made up of Chinese experts who publish their work in Chinese as well. Reliance on their work is akin to drawing from Chinese literature and from experts' work, who have been actively involved in energy efficiency research in selected Chinese industries and the economy as a whole.

Second, this thesis counterbalances the lack of Chinese literature by drawing from international practices and experiences from other countries in offering policy advice for the current Chinese leadership. For example, Turkey is one of the most ambitious performers in the steel industry in recent years. It has registered one of the highest rates of output growth at 42% and capacity utilization growing by 28% since 2009. The country is targeting to be Europe's biggest steel supplier by 2023, also claiming that Turkey has successfully managed to convert the global crisis into an advantage for its steel industry (SBB, 2013k). Building on transferrable experience thus presents a convincing evidence-based case for certain policy directions. What lead to good results? What is transferrable to China versus what is country-specific? This approach is a cornerstone of this paper's research methodology.

Both the LBNL's extensive numerical work and interesting transferrable policy choices have paved the way and have provided a solid foundation on which this thesis is built.

There are important limitations to this paper. First and foremost, it assumes away political economic factors, which are indeed very powerful in China but also the rest of the world. Steel mills are large, important sources of revenue, enjoy special positions with local authorities because they are large employers and they are recipients of central government funding which trickles down to many adjacent "mining towns" and local branches of industry. Many efficiency increases entail politically difficult steps such as industry consolidation, mergers and plant closures based on performance, rather than preference. This thesis offers recommendations irrespective of their ease of political implementation because it considers improvements on the margin – as is expected of an economist's work.

Second, no single piece of data analysis will form the backbone of this paper thus limiting its transferability to other cases. Various data will support different policy recommendations. This is necessary because offering aggregate, economy-wide recommendations cannot draw from single sources of statistical data or information. The topic, country, industry and the time is too specific and the recommendations too broad to enable me to rely on a single indicator or regression from which I could draw quantifiable results.

From these weaknesses stem the largest advantages of this work. It offers concisely summarized glimpses into the steel industry, which also allow policy makers to familiarize themselves with the industry on a superficial level. This paper is built on technical analyses to offer policy advice. It is directly applicable in a policy context and requires no further stages of dissemination to formulate policy recommendations.

CHAPTER 2 - ANALYSIS

2.1 Current state of steel of affairs

Iron is one of the most common elements found on earth. Over 4% of the earth's crust is composed of iron. It was recognized for its outstanding characteristics in construction and warfare more than 4000 years ago. Its industrial scale importance and production, however, only began 200 years ago with the rise of the Industrial Revolution in the West. Modern production procedures allowed for controlling carbon content and other elements to instill certain mechanical properties for the different uses that steel has today (World Steel Association, 2012a). As more efficient sources of energy could be harnessed during the Industrial Revolution, steel production could be ramped up to yield more meaningful quantities and was increasingly replacing wood as the primary construction material during the course of the 18th century. During this time the procedure of rolling sheet iron and steel was developed, replacing the century-old practice of hammering steel into different shapes. 80% of steel produced today comes in the form of sheets or coils. These sheets can be rolled to different gauges according to end-user specification and the form factor allows for different shapes to be stamped out of the sheets for different uses. In the 19th century, modern technologies for producing steel pipes and tubes were developed, which are instrumental today in the energy transmission and water infrastructures. Techniques for mass production emerged in the 1850-60s, with the invention of the Bessemer steelmaking process. The new technique allowed for large quantities to be produced quickly and cost-effectively simply by forcing high-pressure air through molten iron, thereby rapidly eliminating impurities in the material and turning molten iron into steel in less than half an hour. A competitor to this process was the Siemens-Martin open-hearth procedure, which was slower, but produced higher quality steel by allowing for more precise temperature controls during the steelmaking process. Another important development was the idea to vertically integrate steelmaking during the 19th century. Integrated steel mills took care of the entire production process from turning coal into higher quality metallurgical coke for the reduction of iron ore to rolling the finished product and packaging it for end-users. Industrial-scale production advances were well underway during the course of the 20th century. Two world wars have resulted in the widespread nationalization of steel production among the advanced economies. After World War II, consumer demand supplanted government and military orders for steel. The consumer goods-boom in the 1960s raised demand for sheet steels to be used in auto manufacturing and home appliances (commonly referred to as white goods), and the booming oil and gas sector prompted the development of new high strength steels for pipes. The two major production processes being used today became widespread during the mid-20th century. The basic oxygen steelmaking (BOF) process improves upon the Bessemer procedure by blowing oxygen through molten iron to produce steel, rather than air. "Modern basic oxygen furnaces (BOFs) can convert an iron charge of up to 350 tons into steel in less than 40 minutes – compare this with the 10–12 hours needed to complete a 'heat' in an open-hearth furnace" (World Steel Association 2012a, p. 24). During the 1960s, scrap metal waste from consumer goods provided the ground for the development of recycling in steel. Today, steel is the most recycled material in the world. The electric arc furnace (EAF) was developed to melt down purely scrap steel feedstock into liquid steel. In the process, electrodes are lowered into the feedstock and the current between them produces enough heat to melt scrap metals. EAFs possess many advantages over the larger and more cumbersome BOF procedure. They have lower capital costs, more flexible production quantity adjustment characteristics (hence they are also called "mini mills"), a fast rate of production and they are simpler to build and operate.

Laplace Conseil, a consulting firm specializing in the metal and minerals industries estimates that the construction of new integrated capacity (BOF) costs 800-1200USD/ton, whereas it is 150-300USD/ton for EAF (Genet, 2012). Annual maintenance costs are approximately USD50-80/t for BOF and 10-20/t for EAF. The firm also points out environmental advantages to the EAF procedure. "Steel recycling uses 74% less energy, 90% less virgin materials and 40% less water; it also produces 76% fewer water pollutants, 86% fewer air pollutants and 97% less mining waste." "CO2 emissions are reduced by 58% through the use of ferrous scrap" (Genet, 2012).

The focus and frontier of steel developments shifted to Asia in the 1960s and 70s, most notably Japan and South Korea, who have kept their competitive edge until today. Japanese producers were the first to implement computer-controlled production processes and have achieved efficiency gains as a result of automated production procedures.

The 1980s proved to be difficult for U.S. and European producers, as their equipment was considered outdated in light of large investments and capacity expansions in Asia. Margaret Thatcher has privatized the British Steel Corporation in 1987, claiming that steel production was no longer a strategic national asset. Her radical decision ushered in a new age of steel industry privatization across Europe, North and South America and Asia. State subsidies to keep the steel industry afloat during protracted slumps in demand became increasingly unpopular during the late 1980s and 1990s in Europe, largely as a response to Thatcher's legacy in steel (SBB, 2013i). One of the drivers of Thatcher's decision was a weak steel market, overcapacity and lacking industry performance during the 1970s, as a result of the OPEC oil embargo.

Efforts to improve mini mills across Europe and the U.S. spawned a row of innovations that made their flexible production processes seem to match perfectly with a weaker market. A string of privatizations brought important new innovations, which were globally shared in an exemplary wave of knowledge sharing between established steel powers and new emerging ones:

> Compact strip production (CSP) and a similar technique, in-line strip production (ISP), are prime examples.[12] CSP was developed by SMS Schloemann-Siemag AG. ISP was the result of co-operation between Italian steel specialist Arvedi and Mannesmann Demag (which later dropped out). From these European roots, CSP and ISP are spreading worldwide, including to nations such as India and Brazil. But expertise, innovation and investment flow in all directions (World Steel Association, 2012a, p. 36).

[12] In-line strip production (ISP): The process integrates casting the steel from its liquid form on the one hand and the rolling procedure (where steel is rolled into thinner gauges) on the other. By combining the two procedures the entire production cycle is around 15 minutes.
Compact strip production (CSP): Similarly, this process aims to reduce the distance, energy and time from casting the steel to the finished steel coil.

During the last 30 years the focus of global steel has shifted again. China was beginning to shake off the disastrous effects of the autocratically planned central economy, as economic reforms began in the 1980s. Cumulative Chinese steel output growth since 1990 has been a staggering 255%, surpassing India and the declining west. India registering the second fastest steel output growth rate during the same time period, but lagged behind China by more than 80 percentage points, as seen in Appendix 3.

German steel producers were continually facing competitiveness issues throughout the 90's as South Korean, later Indian and Chinese producers were threatening many of the steel powers in old, established economies. German reunification, rising energy costs and suffocating environmental regulations all contributed to loss of competitiveness on the old continent. Developments lead ThyssenKrupp, one of the world's most reputable and established steel producer, to sell one of its oldest steel mills in Dortmund, a factory that has supplied the second and third reich with armor, weapons and ammunition. Mr. Shen Wenrong, number 44 on Forbes' list of the 400 richest Chinese came to be a true steel pioneer for China's growing appetite for high quality steel. The founder and CEO to date of Shagang Iron and Steel, China's largest privately-owned, and the world's 7th largest steel producer, has bought the ThyssenKrupp mill just 1 month after the factory was put up for sale for close to 30 million dollars. Shen Wenrong had no interest in keeping the steel mill in Dortmund. Within 1 year (2 years ahead of ThyssenKrupp's estimate), Wenrong along with close to a thousand Chinese workers managed to deconstruct and ship the entire factory, translating into a shipment of 250.000tons, to be reassembled in China, near the mouth of the Yangtze River (Kynge, 2009, pp. 23-45).

So great was the demand for high quality steel in China, and more importantly, so great was the technological rift between Chinese and German steel production capabilities in 2004, that shipping one of the oldest structures in Dortmund across the globe could be economically justified. As the seemingly insatiable Chinese hunger for steel sucked in an entire 170-year old steel mill from Germany, so did manhole covers start disappearing all over the streets of Europe, to be sold as scrap metal to the Far East (Muir, 2004).

Tides have turned.

Chinese subsidization-schemes and over-investment in heavy industry have lead to "Steel overcapacity [and] could be as high as 200 million tons [per year]", according to Rosetta Stone Advisors director Andy Xie. This overcapacity translates to 13-14% of global consumption in 2011, mainly in China, which now produces close to 50% of the world's steel. Inventories were further expanded when state-owned mills refused to shut down in spite offalling global demand in the wake of the 2008 financial crisis and the ensuing Euro crises.[13] The crisis put pressure on both steel demand and Dollar/Euro exchange rates, currently leading to the lowest prices of finished steel products since the financial crisis of 2008 (Worldsteel, 2012).

A vast country with a clandestine system of extensive government subsidies, an abundance of cheap labor, the complete lack of any safety and health regulations in many core industries, [14] and an entire economy geared towards the stimulation of exports is threatening to completely overwhelm global heavy industry despite, considerable deficiencies in energy efficiency in steel production (SBB, 2012f). On the other hand carbon emission reduction schemes in Europe and elsewhere are "unilateral and disproportionate to other regions of the world", so Danny Croon, environment director at EUROFER, the main association of European steel producers (SBB, 2012a). President of the German Steel Federation also noted that while the European Union's carbon reduction targets are ambitious, their impact is lessened, as other regions around the world have not committed similarly to the effort (Kerkhoff, 2012). This further increases the strain on European steel producers, as steel production is firmly positioned among the resource

[13] Shutting down and restarting a blast furnace is costly and energy intensive. Steel mills often keep producing steel and piling up inventories rather than shutting down, hoping that the lower demand is temporary.
[14] Conservative estimates say that 5000 workers die annually in mining accidents in China's central provinces like Shanxi. Tens of thousands suffer from respiratory conditions.

hungriest and most polluting industries in terms of carbon emissions per unit of output (SBB, 2012j).

The strategic nature and regional economic importance of steel enterprises makes changes to the industry structure difficult and rigid. Steel industry developments have long lead times, with larger-scale building projects taking up to 3-4 years, and capacity expansions requiring key production facilities to be put out of commission for extended periods of time. In a recent report to The Steel Index, a Tangshan [15] mill noted that local steel mills continue to be important sources of revenue for local governments making it increasingly difficult for Beijing to weed out heavy polluters (SBB, 2012h). In fact, sovereign and sub-sovereign power struggles as well as extensive producer subsidization is a major factor inhibiting energy efficiency increases, as they destroy incentives for demand-based production and offer protection from market pressures.

A recently published book, *Subsidies to the Chinese Industry* tries to estimate the full scope of subsidies that were awarded to Chinese producers across many industries between 1985 and 2005 by collecting information from industry professionals and comparing Chinese prices to international benchmarks (Economist, 2013). The gross value of these was conservatively estimated at USD300 billion over the time period examined. Among the damages to domestic producers the book listed the creation of unproductive and unaccountable giant corporations, barriers to entry, overcapacity and high degrees of permeability between political and company leadership creating a rigid industry structure.

In 2008 Usha C.V. Haley and George T. Haley published and article attributing Chinese competitive advantage heavy in industry completely to energy and industry subsidies, as opposed to low wages. The researchers have observed, "Chinese steel doesn't appear to rely on scale economies, supply-chain proximities, or technological efficiencies to lower its costs," (Haley & Haley, 2008). They revealed that extensive energy subsidies in the steel industry were the primary

[15] Tangshan is a prefecture-level city in northeast Hebei, considered to be a steelmaking Hub. Tangshan Iron and Steel remains one of the most important components of the Hebei Iron and Steel Group, the second largest steel producer in the world after ArcelorMittal.

cause of depressed product prices. Chinese producers could sell steel at approximately 19% lower costs compared to U.S. and European producers.

The Chinese steel industry went through the most radical transformation and growth process during the last decade. The industry has primarily rode on the magic 8% growth figures, an extensive system of state subsidies, which lowered prices of intermediate products throughout most stages of the production process. Steel enterprises continue to enjoy privileged positions among sub-sovereign government entities because of their importance for the local economy.

Established steel production capacities are a response to a nation, which recorded 14% growth in 2007, a booming housing sector and large-scale investment projects all across the country. The overwhelming steel output rise of 13.5% in 2009 is largely attributable to the economic stimulus program the Chinese government has announced as a response to the crisis. Total steel output has grown only 3.1% in 2012. Last year was globally characterized as a "survival year" for the industry, according to UgurDalbeler, chairman of the International Rebar Producers' and Exporters' Association (IREPAS). All major steel mills in China have posted sharp profit declines and record losses in 2012 (SBB, 2012h).

Chinese steel mills' preliminary results **Source of data: Steel Business Briefing**

Producer	2012 result (Yuan)	2011 result (Yuan)	y-o-y change	2012 result in USD at Y6.13/USD1	2011 result in USD at Y6.13/USD1
Anshan I&S	-4.16 billion	-2.15 billion	**-93%**	-678 million	-350 million
Maanshan	-3.72~3.95 billion	69.58 million	**-5446~5777%**	-607-644 million	11.3 million
Valin	-3.1~3.3 billion	70.1 million	**-4522~4808%**	-506-538 million	11.4 million
Nanjing I&S	-580 million	325 million	**-278%**	-94.6 million	53.0 million
Hanzhou I&S	-380 million	300 million	**-278%**	-61.9 million	48.9 million
Shougang	-300~400 million	11.78 million	**-2647%**	-48.9-65.3 million	1.9 million
Xinyu I&S	-0.95~1.05 billion	1.70 billion	**-156-162%**	-155-171 million	277 million
Liuzhou I&S	121 million	362 million	**-67%**	19.7 million	59 million
Hebei I&S	13.8~346 million	1.38 billion	**-75~99%**	2.2-56.4 million	225 million
Benxi I&S	100~150 million	795 million	**-81~87%**	16.3-24.4 million	129.7 million
Xining Special	20~50 million	320 million	**-85~94%**	3.2-8.2 million	52.2 million

Chinese steel output is projected to grow a modest 3-4% this year. The global slowdown in steel industry growth has to be addressed with improving efficiency among existing, installed capacity.

The time for action is urgent, as capacity expansions are still underway in China, but demand has simply eroded and has stabilized around lower growth figures. It is said that advanced countries have a per capita steel consumption between 500 and 600 kg per year. China stood at 260kg in 2005 and has risen to 460kg in 2011, as seen in Appendix 4. Chinese crude steel output is expected to be at 750 million metric tons, while apparent consumption is projected to reach 670mmt, according to Hang Changfu, vice chairman of the China Iron & Steel Association (CISA). This means that Chinese steel production capacity utilization rates would average around 77% in 2013. Overcapacity and high raw material costs are expected to pressure steel producers' margins over the next years, according to senior officials at CISA and Baosteel Group, China's second largest steel producer.

Government officials have repeatedly reiterated their commitment to tackle overcapacity. Most recently, during a State Council meeting and on a visit to China's Inner Mongolia Autonomous region, Permier Li Keqiang and Zhang Gaoli, China's vice-premier have reiterated their commitment to tackle overcapacity in cement, steel and shipbuilding. Zhang Dechen, head of the raw materials department at China's Ministry of Industry and Information Technology, has recently confirmed his resolution towards combating steelmaking overcapacity by outlining his commitments:

1. Calling on local authorities to more strictly implement the central government's policies for tackling overcapacity like the "cutoff points" below which small, inefficient capacities must merge with larger units or exit the market.
2. No new projects for installing capacities should be approved this year (especially for low-end products).

3. Chinese authorities will raise different regulation requirements (production technology, energy consumption, environmental protection) and punish noncompliance with higher taxes and power charges.
4. Beijing will encourage technical upgrades, consolidation and overseas expansion (SBB, 2013a).

Many remain skeptic. China has started addressing looming overcapacity issues in 2005, achieving little, "partly due to ambiguous measures and continuing investment in capacity," (SBB, 2013f). Luo Zhongwei, researcher at the Institute of Industrial Economics under the Chinese Academy of Social Sciences, has observed that "weakening domestic and global demand as well as companies' low-level expansion are factors contributing to China's overcapacity," (Yang, 2013). Luo also cites the country's RMB4 trillion (~USD570 billion) stimulus program to counteract the financial crisis in 2008 has worsened the problem, as government investment policies exacerbated the issue. He concludes by noting that "Local governments' blind pursuit of economic growth and regional protectionism have hindered the central government's efforts to curb excess capacity, because such a move would hurt local GDP growth and employment," (Yang, 2013). To signify the importance of the issue, Xi Jinping, China's new leader since late-2012 has expressed concerns about overcapacity, but industry sources still remark that authorities have failed to capitalize on their promises of curbing overcapacity, ever since it was first mentioned in the 2005 5YP (SBB, 2013f). A major iron ore miner in China's Liaoning province has noted that outdated capacity is simply being replaced by state-of-the-art equipment, thereby not addressing the issue to its full extent (SBB, 2013j).

2.2 Environmental implications

The economic boom in China has brought with itself catastrophic degrees of environmental degradation to all niches of nature and human health. Public pressure is mounting over the environmental situation, which the current leadership has vowed to address. 16 out of the 20 most polluted cities in world are located in China. Improvements are underway in green technology development, but successes are uneven. As of 2013, there are over 85,000 dams in China, harnessing the country's hydropower potential, but it is estimated that 75% of water flowing through Chinese cities is not safe for consumption, not even the cultivation of fish. Half of these water supplies are unfit for irrigation and even industrial use.

The steel industry is one of the areas where the implementation of environmental regulations has failed to address environmental degradation. Chinese commitment to pollution reduction in the steel industry can be termed symbolic at best. By 2015, emissions are to be cut by only 6% in the main steel producing areas in the north: Beijing-Tianjin-Hebei, so vice minister of environmental protection Wu Xiaoqing. These areas consume 42% of China's coal, 52% of its gasoline, "while producing 55% of the country's steel and 40% of its cement," according to Wu (SBB, 2013p). This region is industrially very intensive, consuming around 25% of the country's energy, as seen in Appendix 8. Against the backdrop of the newly inaugurated leadership's firm promise to tackle the country's catastrophic environmental situation, according to current information, steel production implications are marginal.[16]

The 12th Five Year Plan (2011-2015) places a clear emphasis on tackling environmental issues and clean technology. Its three main priorities are sustainable growth, industrial development and stimulation of domestic consumption. Its environmental targets have direct implications for the steel industry: (1) reducing energy use per unit of GDP by 16%, (2) reduction of CO^2 emissions per unit of GDP by 17%, (3) reduction of water use per unit of industrial value added by 30% (KPMG China, 2011b). Appendices 8 and 9 show rapid reductions of energy use per unit of GDP in multiple areas. According to the chart, total energy consumption/unit of GDP has declined by 20% during 1992-1995 and 34% during 1996 and 1999. Overall China has been outperforming virtually all its emissions reduction targets (Levine, Price, Yowargana, 2010).

[16] The Beijing-Tianjin-Hebei regions are said to be blanketed in smog for more than 100 days each year.

A different question is whether these reductions were a result of market pressures and development or coercion by regulations.

The current Five Year Plan also envisions the relocation of steel plants to coastal areas. Logistically, this would put them in a better position to accept overseas coal shipments, as China has violently become the largest coal importer in 2009, as seen in Appendix 11. From an environmental perspective, the relocation would "help redistribute the environmental burden" (KPMG, 2011a, p. 3) from areas which were under heavy strain by air and water-polluting steel mills.

2.3 Predicting the future

Irrespective of the topic of efficiency at hand, a glimpse into the future will give policymakers a picture of what to expect regarding the industry that they have to address. The conclusion of this thesis will show that certain steel production technologies will in fact seem better adjusted to the findings of this chapter.

This section will be subdivided into two short sections, attempting a quick glance into the steel industry's future, with focus on Chinese developments. In the first section I will run four regressions looking for relationships between overall economic growth and steel industry output growth between 1990 and 2011 in 14 countries, attempting to search for meaningful and quantifiable relationships between the two variables over a time span of 21 years.

In the second section, I will rely on information from influential policymakers regarding their forecasts, statements and their implications for the steel industry. In the second section I will have established and demonstrated a significant relationship between economic growth, which is the primary go-to statistic for steel industry specialists, and steel industry output in some cases and a weak relationship in others.

2.3.1 By the numbers

Previous literature has indicated that the only meaningful factor affecting steel output in the long run is economic growth (OECD, 2009)(Friedland, 2013)(Ghosh, 2006).[17] This is in fact strongly confirmed by the first two regressions.

I propose two scenarios exemplifying why long term steel output forecasts are difficult. First, steel industry capacity expansions have long lead times, and once capacity has been installed, a smaller country's output will hike considerably because of the typically large amounts of steel that one mill can produce. For example Serbia had a 100% production hike in 2007 after a long period of idling its steel mill at Smederevo, one of the country's largest employers (Steel Statistical Yearbook, 2012). Similar scenarios arise if capacity has been temporarily decommissioned due to maintenance then reinstated to produce at full capacity. These sudden hikes throughout countries' steelmaking histories cause noise in forecasting.

In a second scenario, we can assume that capacity is installed but due to economic fluctuations, it has a capacity utilization ratio below 100%. In these cases upward adjustment of production is easier. Output growth in a country where utilization ratios are around 75-77% (as is currently the case with China) would be certainly easier to predict. However, in reality many "wild cards" will come to invalidate short-term predictions of output growth. For example, the overwhelming steel output rise of 13.5% in China in 2009 is largely attributable to the economic stimulus program the Chinese government has announced as a response to the crisis (Yap, 2003). While new capacity was indeed added in 2009, some of the output growth is simply attributable to raising utilization ratios in selected steel mills.

These factors all reinforce the notion that we have to rely on aggregate economic indicators and analyze long periods of time to discover meaningful relationships. In this section I will build

[17] In addition, certain niches of manufacturing sector growth (vehicles, white goods) as well as construction (railways, infrastructure projects, housing projects) have been shown to influence steel output. Gathering information from these sectors across 14 countries, while accounting for temporary growth and different definitions within manufacturing sectors would have exceeded the bounds of this study, which is not primarily concerned with steel output growth contributors.

four simple linear regressions by Ordinary Least Squares on panel data for 14 countries (later subdivided into 7 developed and 7 developing or newly industrialized countries), analyzing steel output growth and economic growth between 1990-2011.[18]

The four regressions for (1) entire population, (2) sample developing, (3) sample developed and (4) China respectively:

(1) $$steel\_output\_growth\_all = \beta_0 + \beta_1 econ\_growth\_all + \varepsilon$$

(2) $$\widehat{steel\_output\_growth\_dvp} = \alpha_0 + \alpha_1 econ\_growth\_dvp$$

(3) $$\widehat{steel\_output\_growth\_dev} = \gamma_0 + \gamma_1 econ\_growth\_dev$$

(4) $$\widehat{steel\_output\_growth\_cn} = \delta_0 + \delta_1 econ\_growth\_cn$$

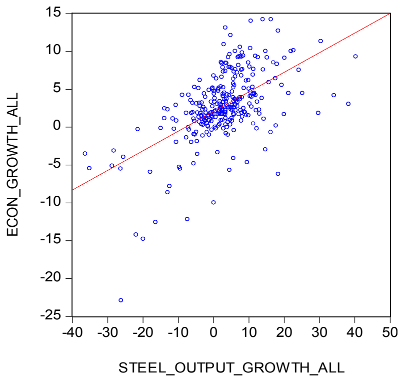


Figure 7 Correlation between economic growth and steel industry output growth in the entire population.

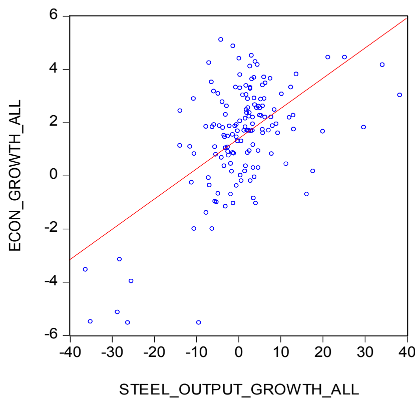


Figure 8 Correlation between economic growth and steel industry output growth in the developed sample comprising 7 countries.

The first regression contains the entire sample of 14 countries between 1990 and 2011. As previously assumed, economic growth has a significant impact across the entire sample regarding steel output. **The results suggest that on average and holding all other factors constant, a 1% increase in economic growth will lead to an increase in steel output by 1.2%.** Yet, only 32% of variation in steel industry output is attributable to economic growth, indicating the presence of other factors, presumably short-term fluctuations. Overall, across the 14 countries included in the sample, there is more than a 56% correlation between economic growth and steel output growth between 1990 and 2011.

In the next step, I will subdivide my sample between the

[18] Developed: Germany, Italy, France, USA, UK, Japan and South Korea.
Developing or newly industrialized: China, India, Brazil, Russia, Turkey, Mexico and Ukraine.

developed economies (USA, Germany, France, Japan, South Korea, Italy, UK) and the developing or newly industrialized economies, with the highest steel output (China, India, Turkey, Brazil, Mexico, Russia, Ukraine). These countries are all among the top 20 producers of steel.

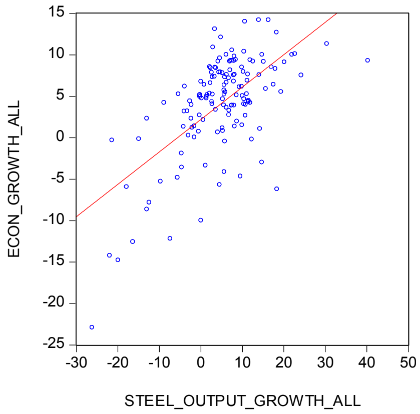


Figure 9 Correlation between economic growth and steel industry output growth in the developing and newly industrialized sample comprising 7 countries.

The regression shows that **on average and ceteris paribus, a 1% increase in economic growth among developed countries will raise steel output by 2.9%.** This translates into a 1.7 percentage point higher significance compared to the entire sample. There is a marginally higher, 62.8% correlation between steel output growth and economic growth among the developed countries, which is 6.8 percentage points higher compared to the entire population.

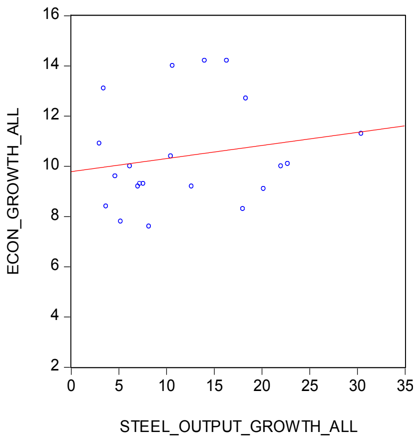


Figure 10 Correlation between economic growth and steel industry output growth in China.

In the next regression, I take a look at developing and newly industrialized countries. These results suggest that **on average and holding all other factors constant, the relationship is unit elastic.** A 1% increase in economic growth is going to be met by a 1% increase in steel industry output. There is a 46.5% correlation between the two variables. These results perform below the entire population and well below developed countries, contradicting many of our previous statements concerning mature and developing market growth.

Now we will check how China fares compared to developing and developed economies. The correlation here is only 19.1%. These results seem insignificant, hinting that **over the time period examined and on average, ceteris paribus economic growth has not impacted**

steel output growth, using this model. It is important to note the small size of the sample. Also see below table for individual correlations between economic growth and steel output growth.

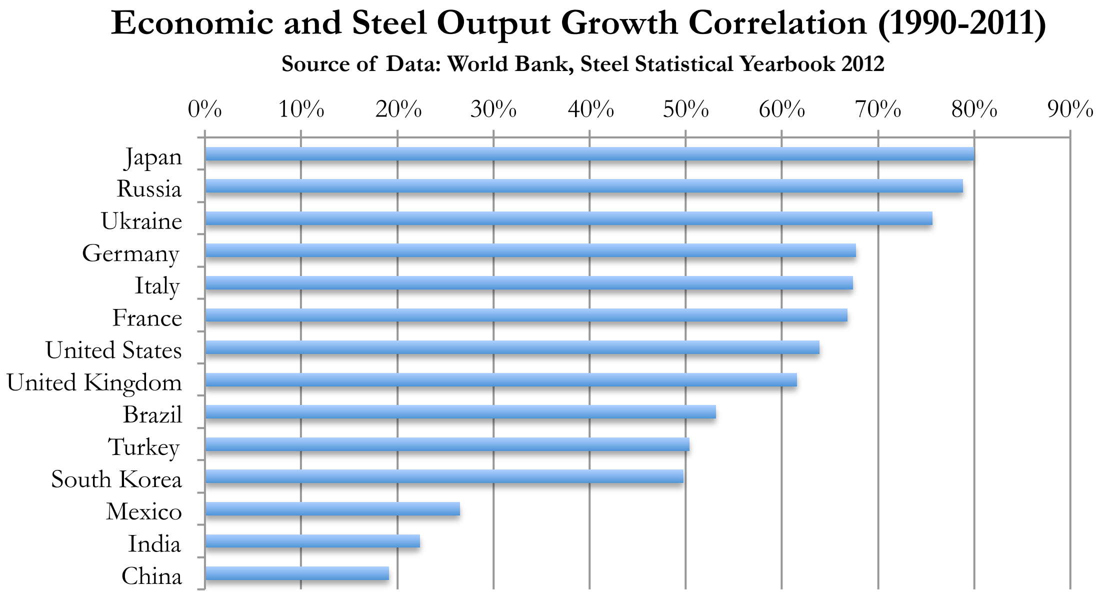


Figure 11 Correlations between economic and steel output growth across the entire population.

The interpretation of these results is difficult and, if we consider the constraints of this simple model, seem to predict exactly the opposite of some of the statements made even in the introduction. Specifically:

(1) We have assumed that due to a strong manufacturing sector, where China is more than 14% above the BRIC-average in manufacturing sector size, in less mature economies, steel industry growth and economic output would be more tightly correlated than in developed economies. In reality, there is a 16.3 percentage point difference in correlation between the developed and less developed country aggregates.

(2) There is a distinct possibility that short-term factors that were discussed (output hikes, stimulus packages, new capacities suddenly coming online, short procurement phases in large infrastructure projects) have a larger impact in developing economies than in developed ones.

(3) As seen in the above table, the correlation between industry-output growth and economic growth is by far the weakest in China. As hinted before, frequent stimulus packages may have invalidated economic growth as a long-term predictor.

The implications of these findings are quite important for gauging future developments "by the numbers", yet it is important to recognize the many limitations of this simple model. Policymakers should not orient themselves on the go-to statistic of the steel industry, namely aggregate economic growth in the developing sample. This is especially true for China because of the historic, 19.1% weak correlation between the two variables. To be fair, the sample size was quite small only covering 21 years for one country. A lot has happened in China since 1990, particularly volatility across steel industry output, economic growth, large-scale industrialization and numerous stimulus packages. Also, as hinted earlier, meaningful steel capacity production expansions in China only began in the 1980s and 1990s, preventing me from drawing from a larger sample. It would have been possible to control for stimulus packages by including dummy variables into the regression, however, because we are interested in long-term developments, the inclusion of "wild cards" in the form of stimulus packages or large infrastructure projects would have contradicted the very reason I constructed the regression and would have damaged its predicting power.

As seen throughout all scatterplots, heteroskedasticity is a serious issue. Therefore, this simple regression loses its prediction power when looking at extreme growth figures either in the economy or steel industry output. The range of the extremes is best described by looking at standard errors from the mean:

Economic growth (developed)	2.6% (std)	2.2% (mean)
Economic growth (developing or newly industrialized)	6.3% (std)	3.7% (mean)
Steel output (developed)	10% (std)	0.7% (mean)
Steel output (developing or newly industrialized)	9.5% (std)	4.8% (mean)

One should proceed with caution when looking at steel output or growth figures that are considerably beyond these numbers.

If we consider the aforementioned long lead-times in heavy industry construction and the likely importance of short-term factors, we can conclude a dangerous mix of short-term, volatile events impacting an industry with generally slow capacity adjustments. Bear this conclusion in mind, as it will directly feed into the advantage of the so-called Electric Arc Furnace steel producing technology that will be discussed in detail later.

Assuming a different perspective, these findings are beneficial in a scenario where policymakers aim to keep a strong market share in international markets, especially developed ones. Among the developed nations, there is a 62.8% correlation between industry output and economic growth. Economic growth figures could be used as a valid predictor of steel demand in the developed world, for export-focused producers to adjust volumes to. China has indeed registered tremendous increases in market share in advanced economies in the recent past, prompting a row of trade disputes and sanctions from the European Union.[19]

[19] Most recently the imposition of anti-dumping duties ranging from 12-57.8% on certain Chinese organic coated steel products. See Commission Regulation (EU) No 845/2012of 18 September 2012 (Bilby, 2012).

2.3.2By the experts

This section will summarize the opinions of selected experts regarding future developments in the steel industry that are of importance to China. I will assume a less quantitative approach in an effort to counterbalance the deficiencies of the econometric model and to try to account for short-term factors that are presumably significant and cannot be adequately caught in the model. Furthermore, after discussing the history of steel, considering future paths will give a well-rounded impression of the steel industry in China and on a global scale. I will use a table to summarize opinions in a convenient framework for quick understanding. The first part of the table will contain short-term, year-to-date and industry predictions for 2013, with focus on China. The second part will look at predictions beyond 2013.

Short-term predictions, year-to-date and 2013 analyses			
Date	**Official/Entity**	**Position**	**Comment**
May, 2013	Li Keqiang	Premier, P.R.C.	➢ Stimulus and investment programs for 2013 are unlikely, no centralized driver of economy
May, 2013	Lakshmi Mittal	CEO, Chairman, ArcelorMittal	➢ Economic conditions in global steel remain challenging ➢ Focus on most competitive assets ➢ Asian, African and CIS units registered highest losses
2013	China's National Development and Reform Commission	-	➢ Steel production in China reached "plateau", modest growth in the future ➢ Only 4% production increase in 2013 ➢ Slowly recovering downstream demand ➢ Recent high iron ore prices due to price-setting among global miners pressure margins ➢ Chinese steel production is fragmented, weakening the industry's bargaining position vis-à-vis iron ore miners
May, 2013	Deng Quilin	CEO, Wuhan Iron and Steel Group Corporation	➢ Market pressure has forced the company to cut prices in May ➢ Producers were enthusiastic at the start of 2013, after a weak market in 2012 ➢ Expectations of rising demand turned out to be false
May, 2013	Wang Quoqing	Analyst, Beijing Lange Steel Information Research Center	➢ New central leadership change in late 2012 brought about new local leadership who are careful about large infrastructure expenditures ➢ Delayed railway projects impacted steel demand
May, 2013	Qu Hongbin	Chief China Economist, HSBC	➢ Slow growth of manufacturing in April 2013 ➢ Fragile growth recovery of China after a weak 2012

			➢ Deteriorating external demand pressures destocking among steel distributors
April, 2013	Eurofer, European Steel Association	-	➢ As long as Chinese production doesn't adjust to weak domestic demand, the European market will continue to be under pressure ➢ Exports from China continue to strengthen in Q1 2013
March, 2013	Zacks Equity Research	-	➢ Emerging economies will be main drivers of steel industry growth in 2013 ➢ Volatile prices could stabilize on the backs of developing countries such as India ➢ In China, government policies, rising loan growth and strong focus on infrastructure will drive demand
March, 2013	Goldman Sachs Group	-	➢ Cuts estimate for global iron-ore prices, on moderate Chinese demand and slow output growth ➢ Weak start into 2013 and weak construction industry outlook throughout the year ➢ Steel production growth will remain below GDP growth in the future
March, 2013	He Wenbo	CEO, Baosteel	➢ A new period of steel demand stability has come ➢ 2013 will be marginally better than 2012 for steel ➢ Producers need time to adjust to slower demand growth than in the past
Long-term predictions beyond 2013			
Date	**Official/Entity**	**Position**	**Comment**
May, 2013	Zhang Gaoli	Vice-Premier, P.R.C.	➢ Reiteration of leadership's commitment to tackle overcapacity ➢ Doubts remain whether the Chinese leadership will follow through
May, 2013	Julian Jessop	Chief Economist, commodities, Capital Economics	➢ Recent, slower Chinese steel output growth is structural, rather than cyclical ➢ No more room for rapid output growth like in 2000s
May, 2013	Ian Roper	CLSA Commodities Analyst	➢ Chinese crude steel production peak: 800m ➢ Less Government spending on infrastructure in the future ➢ Chinese economic growth to stay around 7-8% until 2015
2013	Marcel Genet	Founder, Laplace Conseil	➢ Strong correlation between GDP/capita and steel consumption/capita in China; implication that steel consumption has room to grow ➢ Chinese steel demand growth has benefited miners with higher margins and has squeezed steelmakers
2013	Mike Elliot	Global Mining and Metals Leader, Ernst and Young	➢ Capacity utilization rates will remain below 80% ➢ Overcapacity key issue in 2013 and beyond ➢ Likely improved profitability in 2014-15 due to plant closures

			➢ Political interference will likely impact rational decisions
April, 2013	World Steel Association	-	➢ Forecast for steel output growth rates: 3.5% in 2013; 2.5 in 2014
December, 2012	Changyong Su	Secretary General, China Iron and Steel Association	➢ Global steel prices are expected to stabilize but not recover due to subdued demand ➢ Only slight increases in steel industry output in the future ➢ Turning loss into profits will be challenging for steel enterprises
May, 2013	Rio Tinto	-	➢ Chinese steel demand to hit and peak at 1 billion tons in 2030 ➢ Annual average compounded steel consumption growth of 3% in China in the future ➢ Optimistic long term outlook for the industry despite global growth slowdown
May, 2013	Alan Chirgwin	General Manager, BHP Billiton	➢ Global iron ore supply to grow at a faster rate than demand over the long term ➢ Low-cost suppliers like Australia and Brazil will eventually meet, then exceed Chinese demand
May, 2011	David Ko	Partner and Sector Leader, KPMG	➢ Following changes expected in the Chinese sector between 2011-2015: increased M&A for more efficient production; restrictions on capacity expansion; greater emphasis on high-end steels; relocation of iron and steel companies to coastal areas

Sources: (KPMG China, 2011a) (Friedland, 2013) (Yap, 2013) (Gutierrez, 2013) (Yunyu, 2013) (Kerkhoff, 2013) (Elliot, 2013) (Eurofer, 2013) (EUROFER Market Outlook, 2012) (Sedgman, 2013) (SBB, 2013e) (Zacks Equity Research, 2013) (Hernandez, 2013) (Hook, 2013) (Changyong, 2012) (World Steel Association, 2012b)

The table above should provide a thorough picture of the Chinese industry, where it stands globally and future development trends from Chinese and Western experts and policymakers. Opinions generally converge along a handful of trends and future scenarios:

- Global economic conditions weigh heavily on steel demand
- Lacking demand in downstream sectors (primarily construction and manufacturing) puts steel producers under pressure
- The global steel market is heavily dependent on Chinese developments
- China will enter a less volatile, more mature stage of steel demand growth (2-3.5%/annum)
- Chinese steel demand is sensitive to leadership commitment to large-scale infrastructure projects

- Problem of overcapacity remains key issue, creating distortions between supply and demand

The conclusions reached in this chapter are important with respect to future developments in the Chinese steel industry. I will conclude this chapter by emphasizing the three most important results. First, producers and policymakers should proceed with caution when looking at their go-to statistic in gauging future demand, namely economic growth. Second, overall Chinese economic growth provides poor indication of steel demand growth, as shown by the regression. This adds a dimension of unpredictability. However, export-oriented producers can rely more on growth figures in destination countries, where growth and industry output is more tightly correlated. Third, steel demand in China has entered a slower and more mature phase of growth, which is currently exacerbated by domestic and world economic woes.

CHAPTER 3 – POLICY RECOMMENDATIONS

Finally, after providing a glimpse into the history of steel and setting the stage for the current predicament, offering both empirical and quantitative predictions for future developments in the industry, this chapter will aggregate all evidence, analysis results and formulate policy options that either logically result from the data and/or have been shown to have worked under similar circumstances in the past. This chapter will also further support the recommendations by offering evidence beyond the findings of the analysis. To build the most convincing case, previous endeavors that support the policy recommendation will be outlined as well as weaknesses with current policy stances.

(1) Incentivize and reward adding value to steel in order to perform strongly on domestic and international niche markets.

Current practices of wide-scale subsidization of energy create distorted industry structures where steel producers are not forced to think on the margin and keep expanding capacities. Leadership has continued to reiterate its interest in consolidating the industry, but has failed to capitalize on its promise, due to subsidies and powerful local government support, as pointed out earlier.

The Chinese capacity glut has paved the way for China to export, and to do so in significant quantities. Steel exports alone are an unreliable source of income, as ex-China shipments show a high degree of volatility, subject to international prices and foreign demand. Export performance is therefore a necessary, but not sufficient condition to

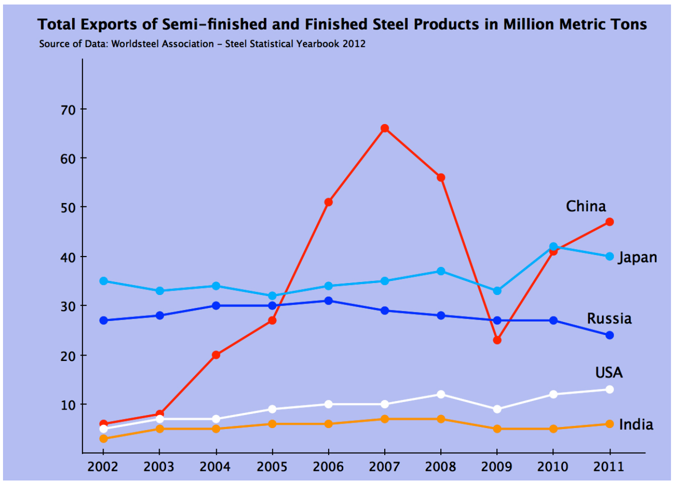


Figure 12 Total semi-finished and finished steel exports of selected countries.

CEU eTD Collection

maintain competitiveness. Concentrating on higher value-added steel exports has three principal advantages:

1) The three major cost factors in producing steel are energy costs, raw material costs and wages. As steel is continually worked (as value is added), the ratio of energy and raw- material costs is decreasingly significant in the cost structure of the end product, vis-à-vis labor costs. Casting the steel is in fact the most energy- and raw material intensive process. Adding more value in terms of human capital lets Chinese competitive advantage to come to full fruition, which is vitally important as raw material costs are rising.

2) Higher margins can be secured with high value-added products, which incentivize R&D for further efficiency gains or smart capacity expansions.

3) International raw-material price volatility and price has increased significantly in the last decade (Oster, 2008). Producing a product where the end-user price is less raw material input-cost dependent will help predictable exports and long-term competitiveness in niche markets.

Figure 13 The significant rise in global coal prices is often attributed to China's huge demand.

Current practices of hard capacity expansions are not the way to go. China is in a more advanced stage of development, which permits producers to focus on adding more value to steel, rather than adding more steel into an already saturated market. Appendix 6 shows, that world capacity utilization ratios have averaged around the 73-78% percentage mark, below the 80% that is considered profitable.

In order to be competitive in higher value added steel, energy efficiency has to improve, to make better usage of existing capacities, rather than adding new ones.

Wolfgang Eder, CEO of successful Austrian steelmaker Voestalpine has noted that Europe is facing a similar dilemma: Many European steel works have lost their competitiveness a long time ago, but are kept artificially afloat by subsidies. If conditions do not improve, half of current

European steel production capacity will be lost by 2030 (SBB, 2012j)."It would be better to use part of these subsidies to finance a proper restructuring of the industry, labor foundations, redeployment plans and the like," according to Eder. He also noted that Voestalpine's exceptional performance throughout the crisis was due to investments in "high-quality products," while leaving mass production to Russian, Turkish and Ukrainian steel mills. The future projected growth of the company will come from investments, efficiency gains and processing to address the needs of premium consumers such as car manufacturers and railways.

There are success stories among Chinese producers as well: Wuhan Iron and Steel Group Corporation (WISCO) is the 4th largest steel producer in China, with an established reputation of being one of the highest quality steel mills in China. In anticipation of stronger demand in consumer products in China, particularly cars, white goods and home appliances, the company is making an effort in refocusing output to high strength, extra thin hot rolled steel coils, which could be used as exterior panels in a wide range of products. Normally, hot rolled coils have to go through additional production processes (cold rolling) to be suitable for such purposes. The company is pressing for extra thin hot rolled coils as substitutes for the common cold rolled coils. CRCs are stamped, bent to shape and used in the production of auto bodies. Without cold rolling, 100 kilowatts per metric ton are saved in the production process, according to an official at the company. Additionally, WISCO has been appealing for 1.6mm hot rolled coils to be used, as opposed to standard 2.0mm thicknesses. A 0.4mm thickness reduction translates to 700kg lighter passenger busses. Reducing vehicle weight has been a longstanding goal of auto producers. WISCO has expanded its production of extra thin coils by 30% in 2012 and is anticipating faster growth in 2013. This is an excellent example of how steel industry R&D and energy efficiency improvements have positive spillovers for downstream industries and how niche markets can help recover healthy margins in an industry plagued by overcapacity (SBB, 2013e).

Chinese producer development strategies should resemble WISCO's initiative and Voestalpine's future plans. Where Europe has Ukraine and Russia for lower value-added steels, China has India and Indonesia. India is still in a resource-intensive and construction-hungry state of development, which requires capacity expansions and focusing on lower value-added construction steels. Construction steels are currently abundant in China, under the installed excess capacities. More mature economies have a less voracious appetite for construction steels, and are looking more toward flat steel products, from which shapes for appliances and electronic equipment can be stamped, as opposed to long products such as pipes, structural steels and reinforcing bars, which are most heavily used in construction and urbanizing countries. The entire economy will benefit in the long run from focusing on higher value-added steels, as the Chinese economy will develop into consuming more and more high quality steels. The current, 12th Five-Year Plan lists new energy industries, new materials industries, high-end manufacturing and clean energy vehicles among its seven priority areas for future focus. All these consume high value-added, technologically advanced steels (KPMG China, 2011b).

There is no issue with the subsidies provided to producers, rather, the subsidies have to be targeted better and be conditional on installing modern facilities which increase overall efficiency, reduce pollution and produce better quality steel.

There are generally two ways of incentivizing the acquisition of new capabilities: M&A and R&D. Currently, the government maintains cutoff points, below which plants must merge into larger units or exit the market (KPMG China, 2011a). The implementation of these guidelines is, as pointed out previously, made difficult by sub-sovereign and sovereign power struggles. This has to be remedied, but, as this thesis assumes away political economic factors, it is a different topic.

The current, quantitative capacity expansions preclude an important development for an economy that is steadily exiting its initial, lowly developed state: the concentration on adding value to the products its economy produces. The umbrella term of adding more value applies to offering incentives toward investing in coating lines to treat (galvanize, paint, layer, bathe, laminate), rather than produce more steel; the promotion of the installation of cutting lines to exploit competitive wages vis-à-vis other markets; to force producers to deliver more end products to end clients. Currently, slitting steel coils would cost around EUR15-20/ton in Europe, whereas most Chinese producers can do exactly the same job for EUR6/ton (SBB, 2011). M&A should play a very prominent role in acquiring new capabilities, as many heavy industry enterprises in the West are cash-strapped but possess valuable technology. China's Wuhan Iron and Steel has recently purchased ThyssenKrupp's tailor welded banks (TWB) business,[20] in a bid to expand into the vehicle market and take care of even more of the production process in-house. CEO of Miller Mathis [21] has recently noted that "now is a good time for M&A in the steel industry", (SBB, 2013c) as capacities can be bought at bottom-market rates. The same capacity can be bought at USD2000/st and at USD84/st in differing market environments, he emphasized. Informing producers of valuable technology available for purchase is important, as offering them cash incentives for purchasing from overseas.

If looking at export possibilities, adding value has even clearer benefits. First, the regression has shown that steel demand is more predictable in the long run among advanced economies, as it can be benchmarked to economic growth. Higher value added steels are mostly used in these advanced economies, which gives producers of higher quality steels a more predictable industry to export to. Second, Appendix 13 shows that price levels between Chinese and European producers for higher value-added steel (Hot-dipped Galvanized steel coils, HDG – green and blue graphs) have converged since the mid 2000s, equilibrating profit margins to the benefit of newly entering Chinese producers. The same cannot be said for lower value-added steels (Hot-rolled Coils, HRC – grey area and orange graph).

[20]"Tailor Welded Blanks are made from individual steel sheets of different thickness, strength and coating which are joined together by laser welding. (...) One advantage is to reduce weight. In addition, the structural and crash performance of the vehicle body is improved: thicker or higher-strength materials can be used in highly stressed areas, while thinner sheets or softer deep-drawing grades can be used in other areas." – TWB Company Website, ThyssenKrupp

[21] Globally recognized as the leading investment bank to the global steel, metals and mining sector.

Another recent example has proven so successful that it prompted the imposition of antidumping duties by the European Union against Chinese-produced organic coated steel coils, one of the highest value-added steels (Bilby, 2012). These steels make up the matt white housing of home appliances on the lower end, and comprise the bodies and hulls of vehicles on the higher end. Appendix 15 shows that during the short period between 2004 and Q4 2011, the EU market share of Chinese OCS has risen from 0.5% to 18%, amid a deteriorating period where the European steel market has actually contracted due to the crisis.

Concentration on adding value ensures that existing capabilities are used in a smart manner, which enhances efficiency, raises margins and puts producers into a good position to anticipate a strong Chinese market for high quality steel and competitiveness on international markets.

(2) Motivate producers to focus on EAF expansion and increase the industry's overall reliance on EAF over BOF.

Recall that there are two primary steelmaking processes used throughout the world today: BOF (blast oxygen furnace) and EAF (electronic arc furnace). The former relies on iron ore as a primary feedstock, while the latter uses scrap metal. Much of capacity expansion in China has, as opposed to other countries in recent years, entailed BOF capacity expansions. BOF on the one hand do not require external sources of heat to produce steel, which makes them more efficient during the production process itself. The BOF process also comes with disadvantages such as continued

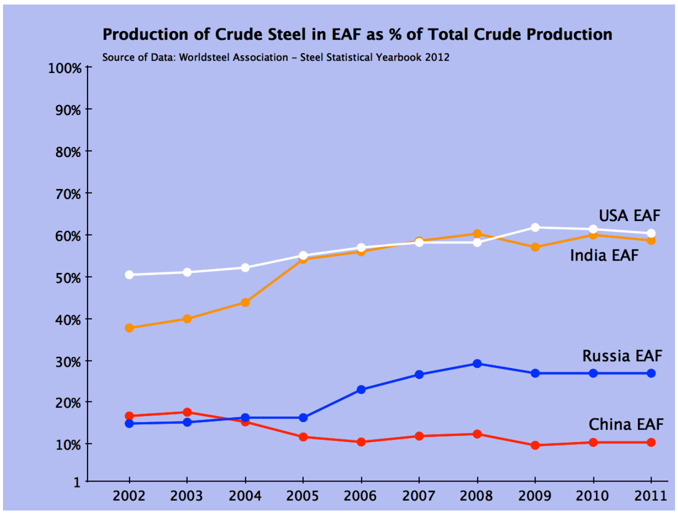


Figure 14 China's EAF utilization rate shows significant deficiencies compared to selected developed and developing countries.

operation and a minimum, rigid annual production quantity of around 2 million tons. Claiming that BOFs are more energy efficient is akin to just considering tailpipe vehicle emissions, as opposed to a life-cycle analysis. EAFs on the other hand, are capable of very rapid production adjustments, if demand were to rise/fall. We have established that domestic and export demand has been very volatile in recent years, so a more flexible production technique benefits this trend. As steel consumption growth is projected to stabilize around lower figures and higher quality in China, EAF caters to this trend as well. BOFs also require long installation times and high capital costs. There have been rapid energy efficiency increases within the EAF process, which make it a very good platform for further improvements.

An analogous success story is Turkey. The country is rapidly expanding its steel production capacities as a response to a bullish economy. According to the Turkish Iron and Steel Producers' Association, "88% of steel production growth in the recent years is attributed to investments and capacity expansion in EAF." As seen in figure 14, China is still considerably behind other countries' EAF utilization rates. In addition, EAF produces steel primarily from scrap metal, as opposed to iron ore in BOF. This increases lifecycle efficiency, caters to Chinese environmental issues which politicians currently emphasize and places producers in a good position to feed off the booming passenger vehicle market in China (considered the main source of scrap). Focusing on a more flexible production process accommodates very well to a saturated and volatile market and more efficient overall production.

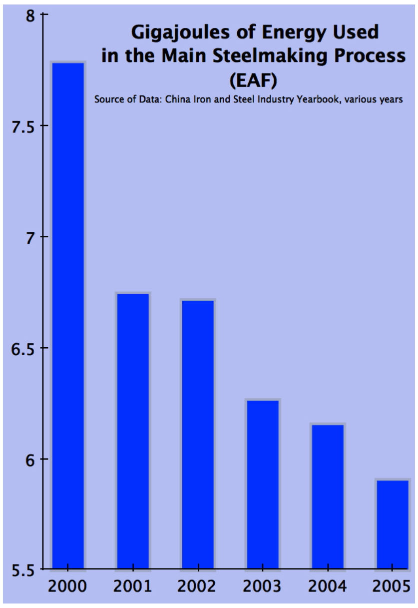


Figure 15 Energy usage averages in GJ/ton among Chinese producers show rapid increases in energy efficiency.

In 2006, China produced 4 times more air conditioners, twice as many TV sets and twice as many refrigerators than in 1999, as seen in Appendix 10. The Chinese passenger vehicle market has outgrown the United States in 2009 in terms of growth rate, sales volume and number of cars produced (Congressional Research Service, 2010). The China Association of Automobile Manufacturers claimed that passenger and commercial vehicle car sales were 19.3 million units in 2012, rising 4.3% since 2011 (Marketwatch, 2013). The "white goods" boom will certainly create a considerable supply of scrap steel, which is the principal feedstock of the EAF steelmaking process.

To incentivize the installation of the EAF procedure, two policy recommendations can be formulated: 1) Introduce conditional subsidies, tax rebates and government support in the form of cheap capital, should producers opt to expand EAF capabilities; 2) Disincentivize BOF expansions and punish inefficient, BOF-centric producers with pollution and energy tariffs. A possible way would be to give producers a 3-4 year adjustment process, after which they have to adhere to a given EAF/BOF production ratio in their total steel output.

(3) Address urgent need for consolidation, ramp up existing efforts.

The current 5YP has delineated industry "cutoff" points, below which producers have to merge with larger units or exit the market. The argument goes that larger producers are more efficient.

Steel production below these cut-off points will be eliminated	
Blast furnace	Less than 400 cubic meters
Converters	Less than 30 tons
Electric arc furnace	Less than 30 tons
Hot-rolled strip	Width below 1,450mm[a]
Hot-dipped galvanized coil	Annual capacity below 300,000 tons per year
Colour-coated sheet	Annual capacity below 200,000 tons per year

Figure 16 Cutoff points specified by the 5YP.

As noted previously, industry sources are skeptical and see no practical implementation of the cutoff points due to steel mills' regional importance and pull with local authorities. Officials will have to ramp up efforts to push for the cutoff. There are two distinct advantages to this policy that none of the others has:

1) It has been established that steel industry lead times are generally long, cumbersome and capital intensive. Forcing closures and mergers is one of the few solutions that will bring results

"the next day." There is no need for the installation of new, more efficient capacity, nor is there a need for research and development or overseas technology purchases.

CEO of ThyssenKrupp, Heinrich Hiesinger recently commented about Gerhard Cromme, a leading figure in the German steel industry that "the mergers of Krupp and Hoesch in 1992 and later with Thyssen in 1999 are results of his forward-looking initiatives and have contributed significantly to the required restructuring of the steel industry" (SBB, 2013l).

The current 5YP also states that small producers have caused quality and margin erosions in the industry. Incorporating smaller producers into larger units brings them new markets, new technologies and a new educated workforce, which are all big advantages when compared to building new capacity. Small producers will benefit from having access to higher quality products, increased capacity and product palette to service their existing customers and attract new ones. Forming larger unites will also improve export performance and promote increased profits through economies of scale.

2) Larger units allow for a unified bargaining front against coal and iron ore importers, namely the three giants Vale, Rio Tinto and BHP Billiton. Appendix 11 shows that China's voracious appetite for coal has put the country into a very vulnerable position as a major importer. Appendix 7 shows China's historic and continued reliance on coal for energy transformation. Today, 70% of its energy needs are covered by coal (Koons & Lee, 2013). Another major important use of coal is its transformation into metallurgical coke by burning bituminous coal in an oxygen-starved environment, thus enhancing its usability in the steelmaking process.

As regards iron ore, China has recently voiced concerns that mining giants Vale and BHP Billiton have engaged in price manipulation by simulating iron ore shortages to drive up shipment prices to its biggest client, China (Reuters, 2013).

Appendix 15 demonstrates that global iron ore prices have shown increased volatility in the recent years, putting further strain on Chinese producers. Unified action by a body of steel producers, which encompass as many steel mills as possible could therefore be instrumental in better leverage in price negotiations.

Small producers and private mills (which currently produce 50% of Chinese steel output (SBB, 2013h)) have to be made aware of the above two points and their importance to their business. They know that under current market conditions, all they can do is live on the margin, extracting meager profits from their existing client networks, while the entire economy is shifting below them. It has also been observed that "…authorities provide little help to private producers either through financing or supportive policies…" (SBB, 2013j). This has to change, as pointed out in the 5YP, small producers take up a large portion of aggregate production and they are more inefficient than larger units. Help has to be extended irrespective of private or state ownership. In addition, smaller mills can more quickly adjust operations to accommodate market changes, which has to be taken into account and rewarded.

Private steel mills with at least 10 million mt/year capacity
Source: Xiben New Line

	2012 steel output	Contribution to total output
Jiangsu Shagang	32.31 million mt	4.5%
Jianlong Group	13.76 million mt	1.9%
Rizhao Steel	13.22 million mt	1.8%
New Wu'an Steel	12.87 million mt	1.8%
Pingxiang Steel	9.12 million mt	1.3%
Jinxi Steel	9.1 million mt	1.3%

Figure 17 Production shares of the largest privately-owned steel mills in China. Source: (SBB, 2013h)

With adequate communication, a "get there first" attitude can be genuinely exploited to incentivize small, fiercely competing producers to merge. The China Iron and Steel Association could be instrumental in publishing success stories of small mergers, while the central government ramps up efforts to coerce unwilling producers to merge and obey the cutoff points.

(4) Divert a larger portion of energy subsidies and steel industry subsidies to R&D in the steel industry and upstream industries.

Throughout this thesis I have demonstrated the large leaps in energy efficiency that Chinese producers were able to achieve. From 1980 to 1991, the energy used in the BOF production process was reduced by 17%. From 2000 to 2005 the reduction was 32% in the EAF procedure.

On the aggregate level, energy intensity/ unit of GDP has constantly performed below the rate of economic growth between 2005 and 2009.

Evaluating government efforts in reaching the goals of the 11th 5YP (2006-2010), Price and his team at the LBNL find that "many of the energy-efficiency programs implemented during the 11th FYP in support of China's 20% energy/GDP reduction goal appear to be on track to meet – or in some cases even exceed – their energy-saving targets" (Levine, Price, Yowargana, et al., 2010, p. 20).

In 2009, China possessed more than 38 times the amount of coal produced in that year on stock (Gang & He, 2010), despite the incredible import hike discussed earlier.

The World Coal Association estimates that USD33 trillion will be needed in global energy infrastructure investments between 2011 and 2035 to keep up with current rising demand and put the planet onto a low-carbon development path. 64% of these investments will be needed in non-OECD countries and China alone representing 16%, or USD5.3 trillion (World Coal Association, 2011). Specifically in the coal industry, the organization finds that 85% of coal consumption increases will come only from China and India, before 2030. Existing producers in India and China will have to facilitate investments in port and railway facilities. Moreover, "In 2010, over 10,000 coal trucks transporting coal to the Western part of China from Inner Mongolia were blocked in a 120km traffic jam for around nine days." The study concludes that Chinese freight capacity grew by record figures but "infrastructure expansion is still not happening fast enough to match the country's growing coal demand."

Chinese iron ore production has grown by 138% between 2002 and 2009. There is no reason to believe that a plateau has been reached, despite the country importing a record amount of iron ore. In 2012 Rio Tinto has sold 147 million tons to China, and is expecting higher figures in 2013 (Mohindru, 2013).

The facts above show three things: 1) there is reason to believe in the existence of unexploited efficiency gains, as China has been performing exceptionally well during the last

5YP, 2) There is room, need and demand for further investments and efficiency gains, 3) China still has untapped potential in many aspects, such as coal reserves.

As the steel industry is very raw-material intensive, improvements should start in upstream sectors with ample investments in making coal reserves accessible and cheap to mine, developing domestic sources of iron ore over ever-increasing imports. Instead of subsidizing energy, conditional subsidies exclusively for the process of extracting iron from iron ore could help in making up for the fact that Chinese iron ore possesses only approximately ~30% iron, versus the higher grade, Australian ore having a ~60% iron content.

Increased infrastructure developments in coal, iron ore transportation could further make domestic resources cheaper to mine. Although of a lower quality, in terms of total reserves, China's iron ore deposits are the third largest in the world.

(5) Maintain a 1+1 strategy for relocating production facilities to coastal provinces.

Shaun Rein, prominent China-columnist for Forbes and Founder of the China Market Research Group argues in his book, *The End of Cheap China* that companies operating in China need to maintain a "China plus" strategy. As the country transitions from a low-wage, manufacturing-sector based economy to a mix of producing higher value-added goods and developing more meaningful domestic consumption, Chinese and foreign companies will have to establish a foothold in other regional, less developed markets such as Vietnam or Indonesia, while maintaining core operations in China in order to "hedge against" the risks of a rapidly changing economy (Rein, 2012).

The steel industry implications of the current 5YP aim to relocate steel enterprises to coastal regions in an effort to reduce logistic costs for seaborne coal or iron ore shipments.

In a study titled *The World's Greatest Coal Arbitrage,* a Stanford University researcher and his associate argue that the dramatic increase in coal imports in China in 2009 is a not a result of dwindling domestic resources, but was in fact a large-scale coal arbitrage because traders exploited a temporary difference in lower international coal prices, vis-à-vis the especially strongdomestic market. They further argue that China has considerable potential for efficiency increases in domestic production by improving transport and infrastructure.

Wuhan Iron and Steel has launched a large project to construct its 9.2 million tons/year Fangchenggang integrated steel worksin southern China's Guangxi coastal province in mid-2012, to commence operation in 2016. WISCO followed a similar move by China's steelmaking giant Baosteel, which aims to construct a similarly large, state of the art integrated steel mill just 200km from the WISCO mill. The two companies aim to reduce raw materials transportation costs and fill an apparent gap in steel production presence in southern China (SBB, 2013o). Both producers remained quiet and have delayed construction in these projects. It has been hinted that a bleak 2012 put pressure on both companies' liquidity for proceeding further on these projects.

The coal arbitrage research highlights that there are still significant opportunities in the Chinese coal and iron ore markets. The country is a leading producer in both, with continually increasing production. A rapidly changing import/export position should therefore not be misinterpreted for a structurally changing economic structure, where China will become overly reliant on imports.

The example of WISCO and Baosteel highlights an important principle that was outlined in the regression: a volatile market impacting a rigid industry with long lead-times, which is slow to adjust. As a reference, the production capabilities of the two envisioned mills would exceed the U.K.'s, Austria's and Hungary's annual output combined. Such violent expansions are outright damaging and suffocating any hopes at recovering margins and adjusting output efficiently and gradually to demand.

Therefore, the current policy outlined in the 5YP of bringing companies to relocate steel works has to be augmented by a more fitting "1+1 strategy." Producers should maintain strong presence in their original markets and gradually build capacity in coastal provinces, for example by building low-capital cost EAF furnaces, while maintaining their core presence at home. Complete relocation is not the way to go. In order to curb newly establishing capacity in new markets such as southern China, production and construction quotas can be assigned per province, for which producers can compete.

CONCLUSION

Overall, the mechanisms needed to address overcapacity and associated energy efficiency improvements are already installed and China possesses a good track record in keeping up with targets. There are, however, issues with implementation and more thought has to be given to ensure adequate targeting of the policies, irrespective of state or private ownership. There are huge leaps in technological efficiency gains among Chinese producers, as they fiercely compete with each other for profits in a saturated market. Structural changes in the industry have to be addressed that cover overall efficiency. In China's particular case, a centrally planned economy is an advantage that has to be exploited, as structural changes can be quicker, more efficient to implement and subsidies merely diverted and better targeted.

Based on a historic analysis, pointing to existing practices and establishing a simple framework regarding the future development of the steel industry, this paper found that there are pitfalls to relying on economic growth for assessing steel industry developments, that policy mechanisms are in place and functioning, but that they have not been adequately targeted to bring about the needed changes without creating perverse incentives. Furthermore an overly BOF-centric industry structure and local governments hinder meaningful progress. With this foundation I could formulate five policy recommendations that are either parametric adjustments to existing 5YP policies or new initiatives.

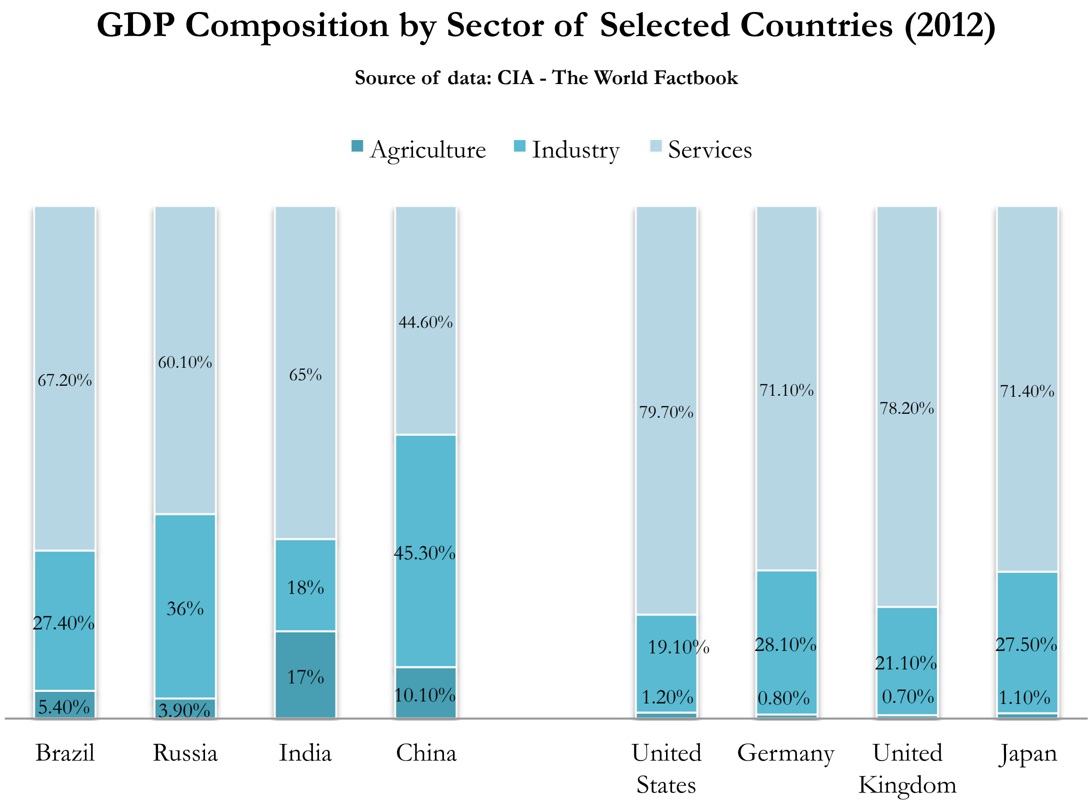
1) Incentivize and reward producers' willingness to upgrade capacities in terms of adding value to steel, in order to perform well on domestic, international markets and recover lost margins.
2) As the EAF production technology is more suited to improve life cycle efficiency, environmental friendliness, address volatile and lower steel demand growth, producers should be incentivized and forced to expand into EAFs.
3) Increase existing efforts at industry consolidation by a) advertising success stories to achieve critical mass among small producers, b) punish non compliers more strictly.

4) Divert a larger portion of subsidies to upstream investments in energy efficiency as well as coal and iron ore mining infrastructure developments.
5) Augment the existing policy of relocating steel mills to coastal provinces by requiring core operations to be maintained at the original location and rewarding gradual and slow EAF expansion, as opposed to building large, integrated steel mills in target regions.

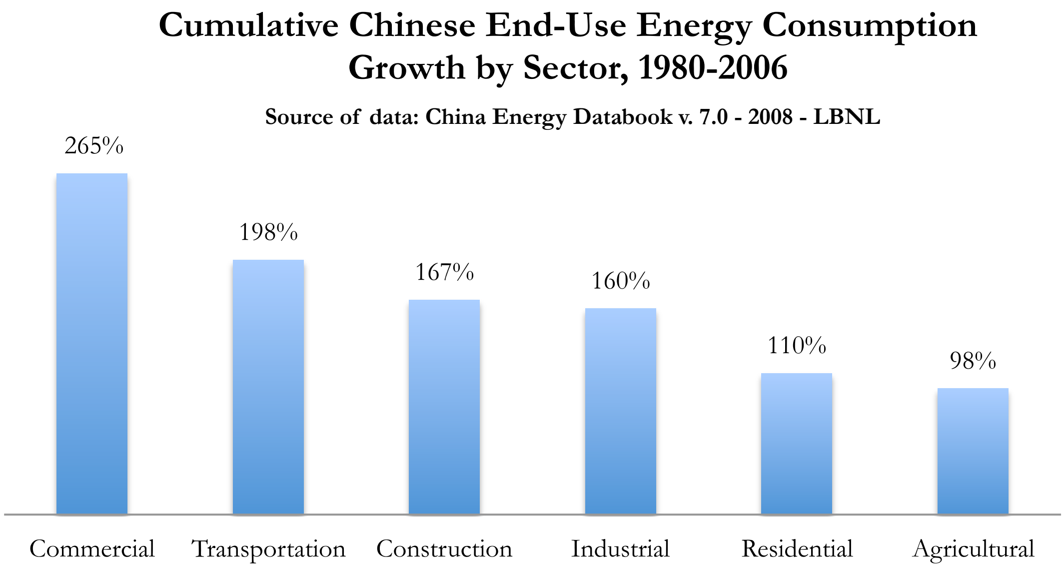
Addressing the issue promptly is of major importance, as first attempts to curb overcapacity and focus on inefficiency date back to 2005, with little done to achieve them, except considerable, technological-related efficiency gains but little progress in structural adjustments. The country will enter a new phase of more mature development. The steel industry employs around 3.5 million people in China. A healthy industry structure is necessary for continuing competitiveness, incentivizing research and development, reducing the environmental burden and ensuring stable growth for one of the most important industries in up and coming China – steel.

APPENDICES

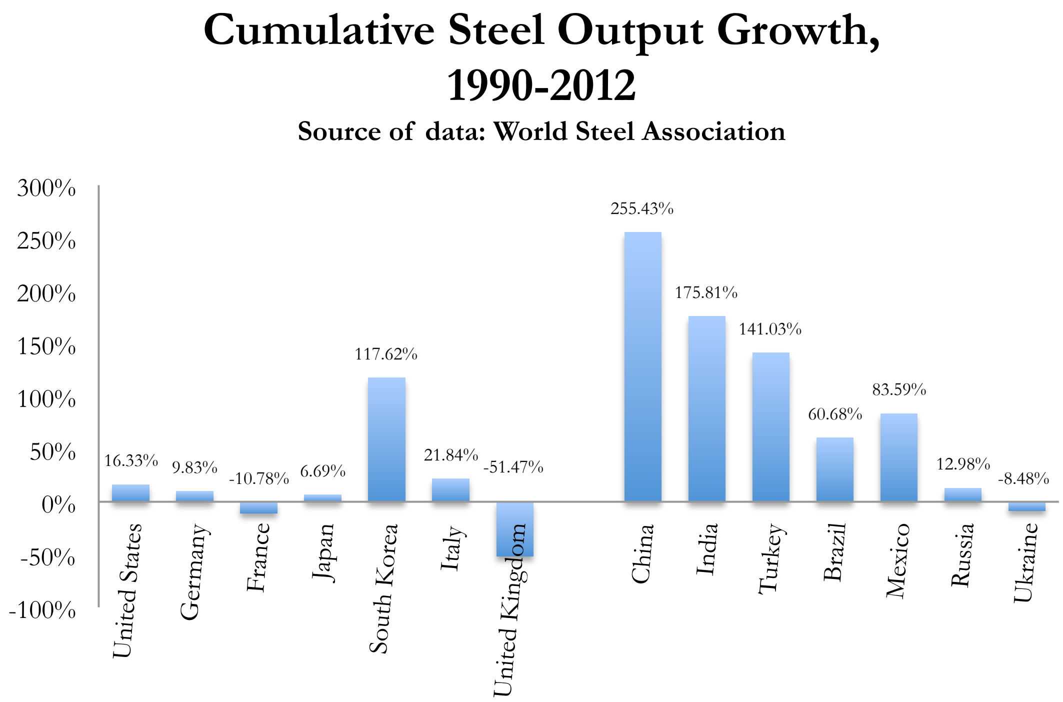
Appendix 1. – GDP composition



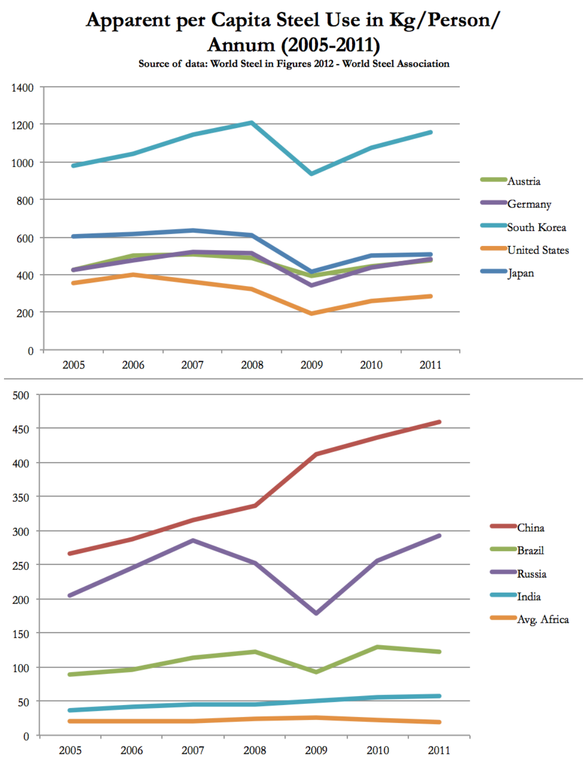
Appendix 2. – Energy consumption growth



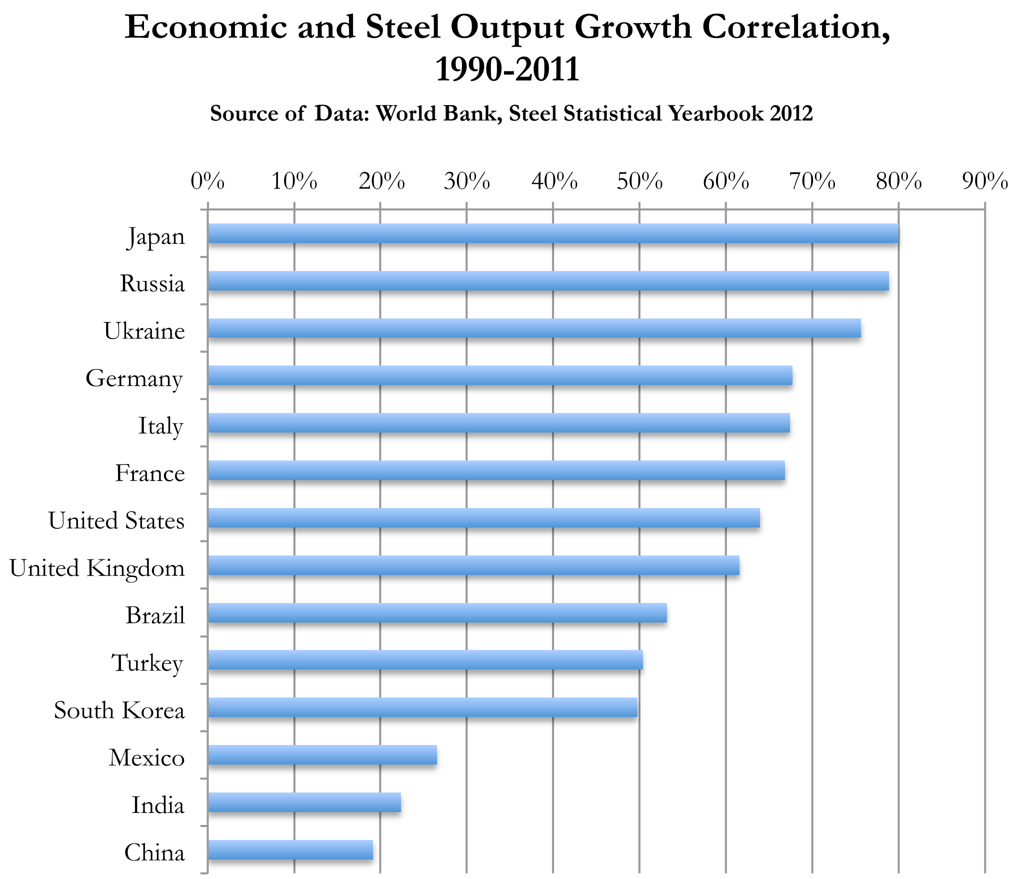
Appendix 3. – Steel output growth



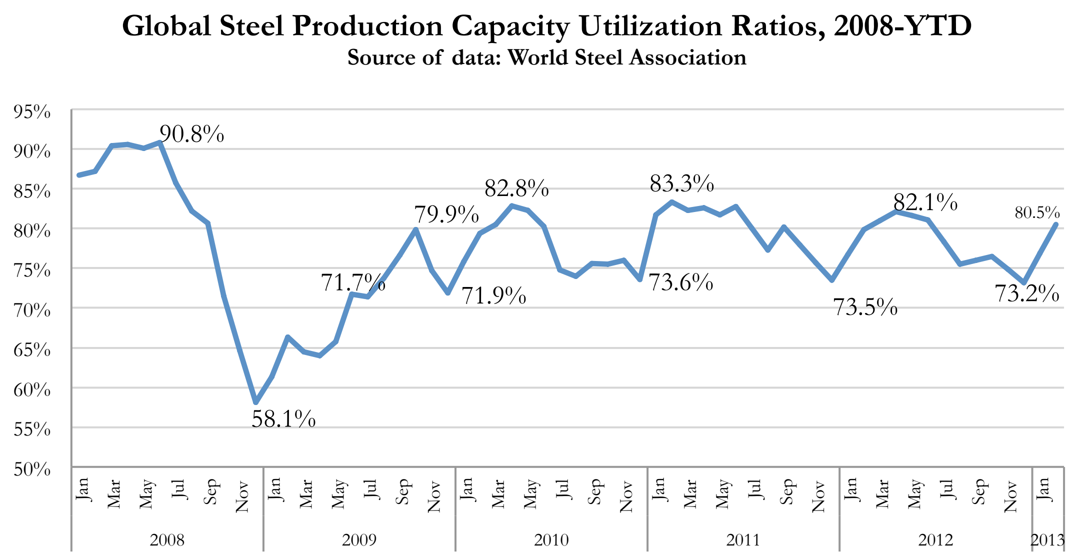
Appendix 4. – Per capita steel use



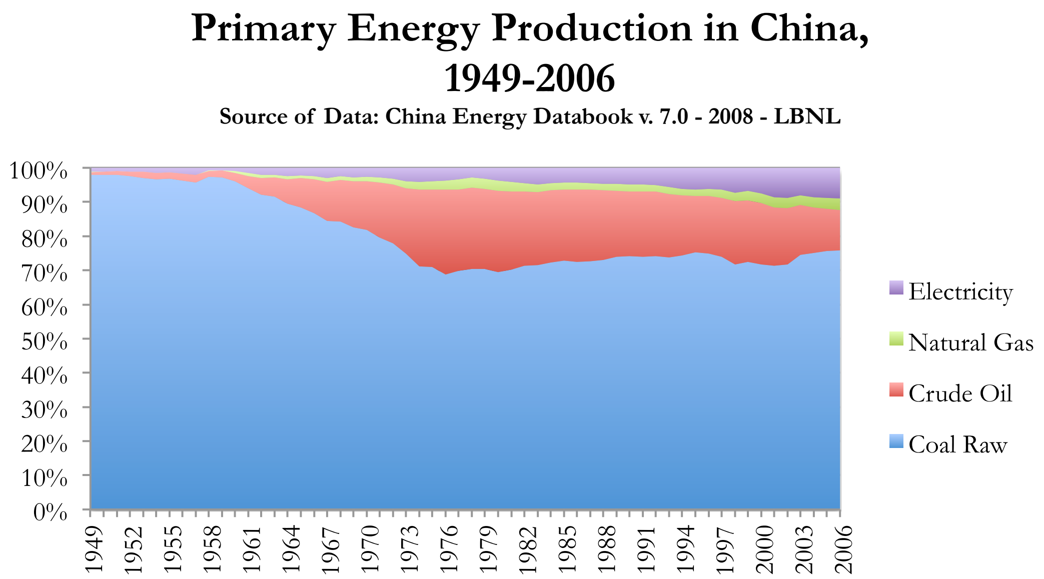
Appendix 5. – Correlations



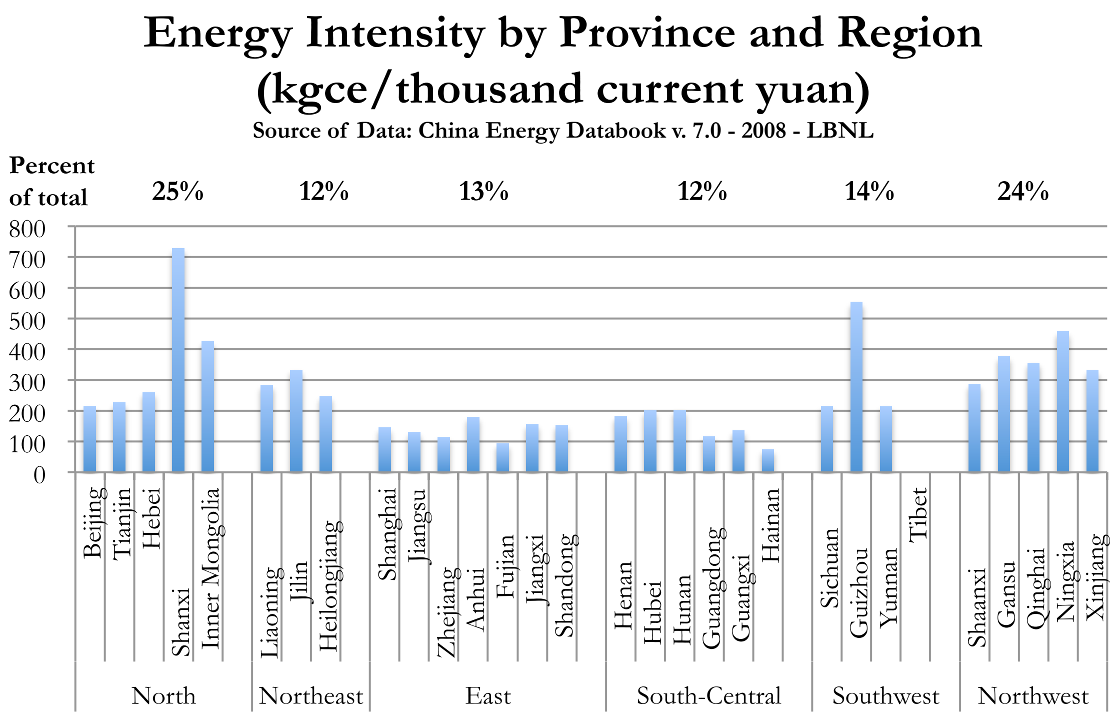
Appendix 6. – Capacity utilization



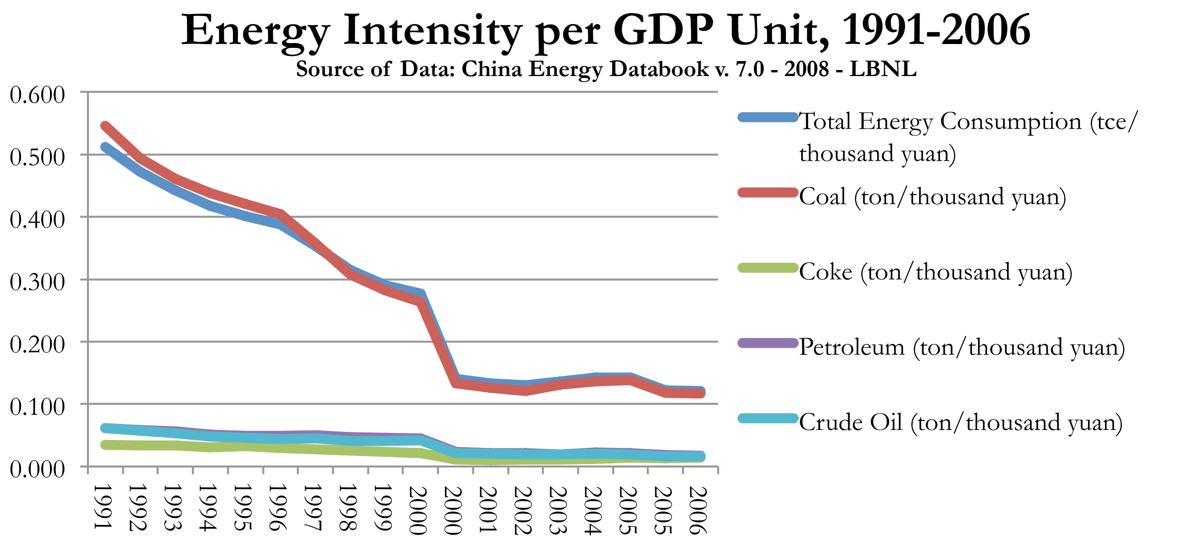
Appendix 7. – Primary energy production



Appendix 8. – Energy intensity, a

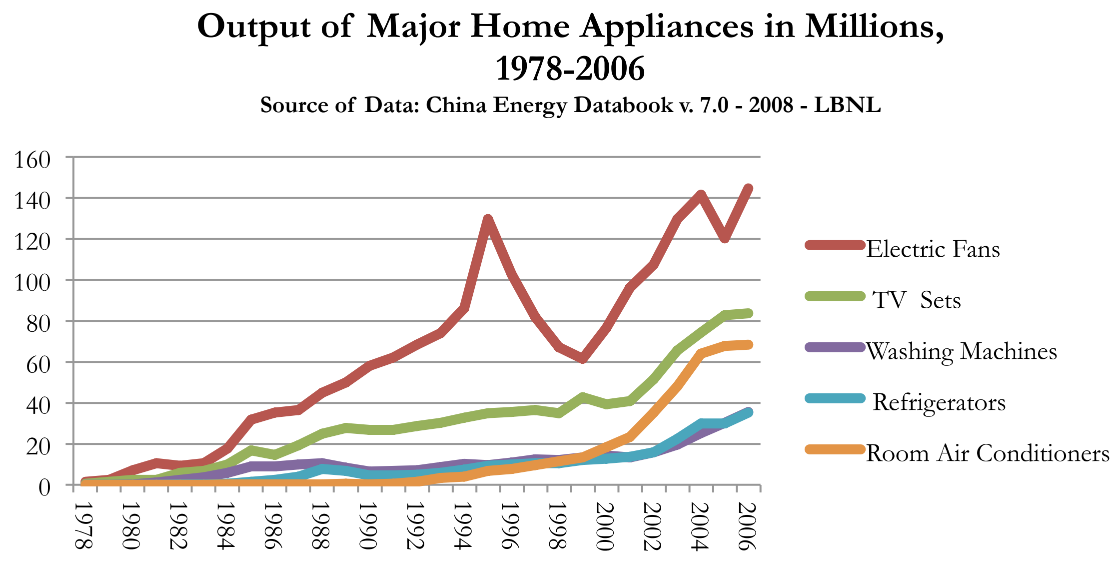


Appendix 9. – Energy intensity, b

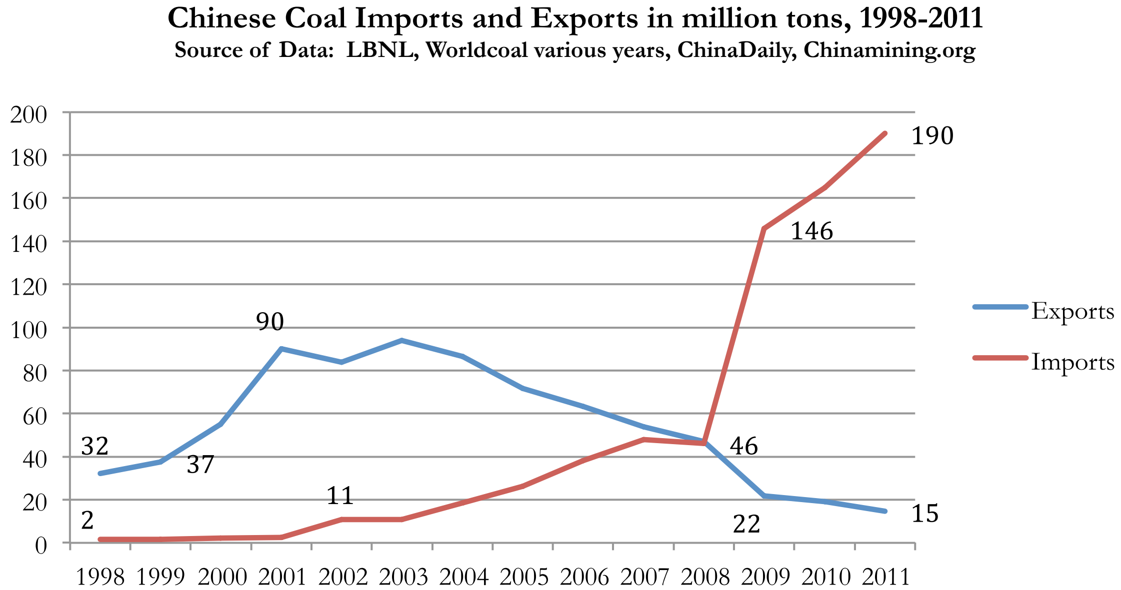


Note: Large dips are attributable to nominal changes in Yuan value. 1991-1999: constant 1995 Yuan; 2000-2005: constant 2000 Yuan; 2005-2006: constant 2005 Yuan.

Appendix 10. – Home appliances output

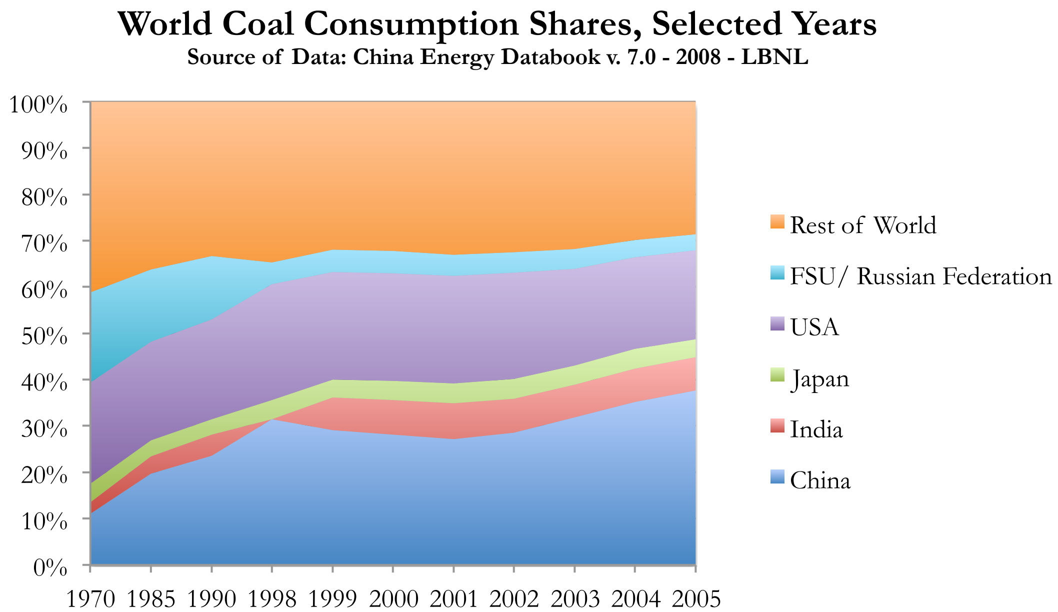


Appendix 11. – Chinese coal imports/exports



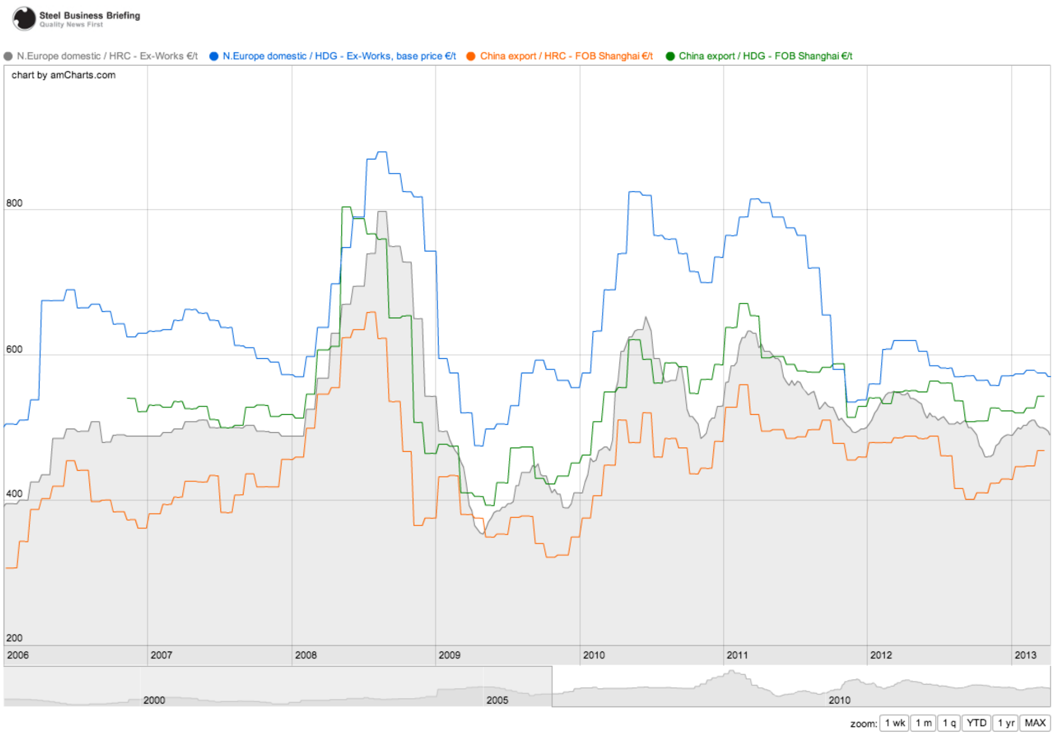
Note:Chart includes all major coal types: anthracite, coking coal and other bituminous coal, lignite, briquettes, and coal slurry.

Appendix 12. – World coal consumption

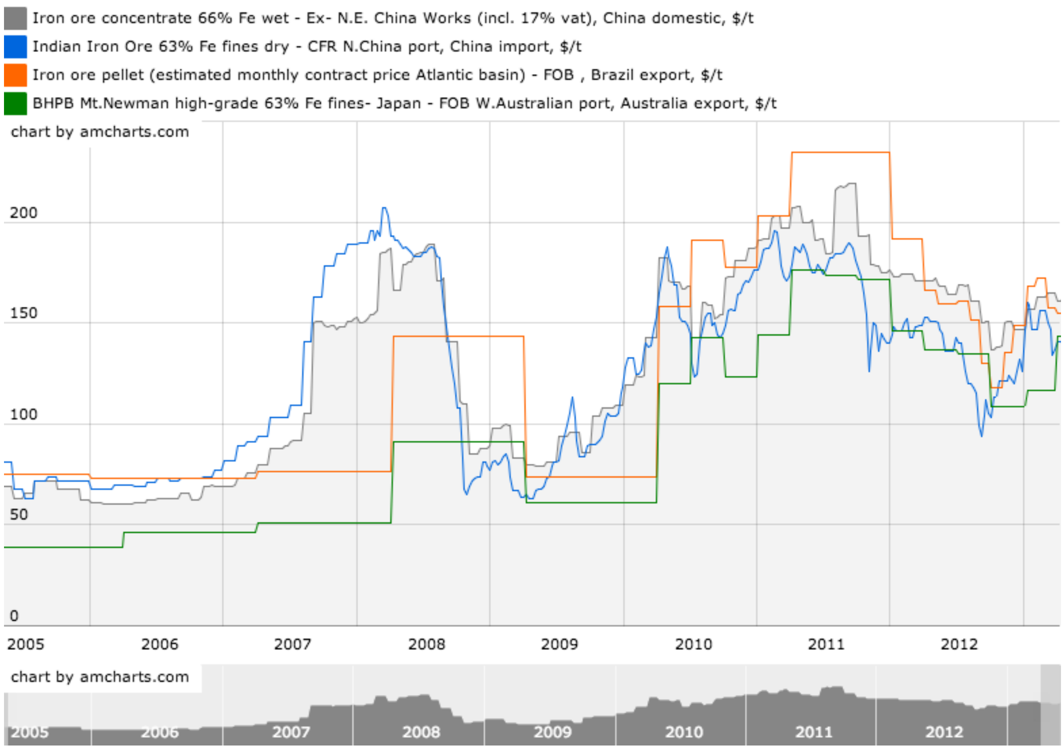


Note: Chart includes all major coal types: anthracite, coking coal and other bituminous coal, lignite, briquettes, and coal slurry.

Appendix 13. – Price level convergence

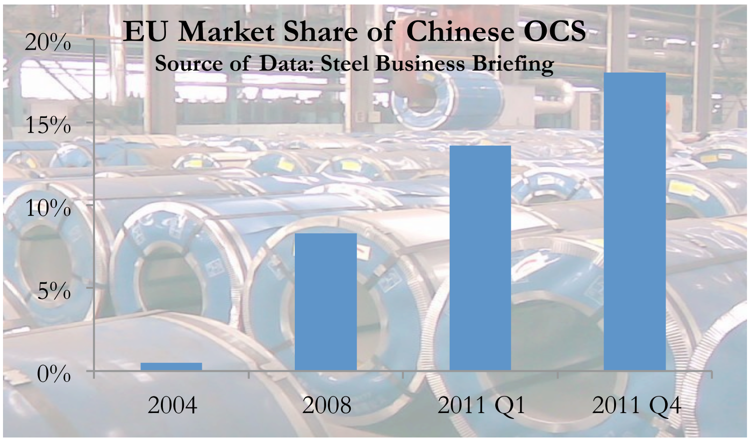


Appendix 14. – Iron ore prices



Description: Grey area: Price charged by producers in China at exit of product from the factory, including 17% VAT; Blue graph: Indian iron ore shipments to China, with price including delivery to a port in Northern China; Orange graph: Price of iron ore pellets after they have been loaded on board a freighter in Brazil; Green graph: Price of iron ore produced by BHP Billiton and loaded onto a carrier at an Australian port.

Appendix 15. – OCS market share



Appendix 16. – Regression outputs

Entire sample

Dependent Variable: STEEL_OUTPUT_GROWTH_ALL
Method: Panel Least Squares
Date: 05/16/13 Time: 19:01
Sample (adjusted): 1991 2011
Periods included: 21
Cross-sections included: 14
Total panel (unbalanced) observations: 290

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECON_GROWTH_ALL	1.237377	0.106146	11.65729	0.0000
C	-0.626593	0.575286	-1.089186	0.2770

R-squared	0.320582	Mean dependent var	2.840793
Adjusted R-squared	0.318223	S.D. dependent var	10.15587
S.E. of regression	8.385678	Akaike info criterion	7.097800
Sum squared resid	20252.04	Schwarz criterion	7.123110
Log likelihood	-1027.181	Hannan-Quinn criter.	7.107941
F-statistic	135.8923	Durbin-Watson stat	2.047707
Prob(F-statistic)	0.000000		

Developed countries

Dependent Variable: STEEL_OUTPUT_GROWTH_DVP
Method: Panel Least Squares
Date: 05/16/13 Time: 19:16
Sample: 1990 2011 IF CROSSID<8
Periods included: 21
Cross-sections included: 7
Total panel (balanced) observations: 147

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECON_GROWTH_DVP	2.903777	0.343899	8.443690	0.0000
C	-3.550554	0.861680	-4.120504	0.0001

R-squared	0.329622	Mean dependent var	0.766395
Adjusted R-squared	0.324999	S.D. dependent var	10.23587
S.E. of regression	8.409632	Akaike info criterion	7.110145
Sum squared resid	10254.68	Schwarz criterion	7.150831
Log likelihood	-520.5956	Hannan-Quinn criter.	7.126676
F-statistic	71.29589	Durbin-Watson stat	1.792834
Prob(F-statistic)	0.000000		

Developing countries

Dependent Variable: STEEL_OUTPUT_GROWTH_DEV
Method: Panel Least Squares
Date: 05/16/13 Time: 19:21
Sample: 1990 2011 IF CROSSID>7
Periods included: 21
Cross-sections included: 7
Total panel (unbalanced) observations: 143

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECON_GROWTH_DEV	1.008869	0.105258	9.584751	0.0000
C	0.781826	0.767121	1.019169	0.3099

R-squared	0.394505	Mean dependent var	4.973217
Adjusted R-squared	0.390211	S.D. dependent var	9.651777
S.E. of regression	7.536975	Akaike info criterion	6.891406
Sum squared resid	8009.644	Schwarz criterion	6.932844
Log likelihood	-490.7355	Hannan-Quinn criter.	6.908245
F-statistic	91.86746	Durbin-Watson stat	1.723227
Prob(F-statistic)	0.000000		

China

Dependent Variable: STEEL_OUTPUT_GROWTH_CN
Method: Panel Least Squares
Date: 05/16/13 Time: 19:27
Sample: 1990 2011 IF CROSSID=8
Periods included: 21
Cross-sections included: 1
Total panel (balanced) observations: 21

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECON_GROWTH_CN	0.702064	0.826501	0.849441	0.4062
C	4.673269	8.769386	0.532907	0.6003

R-squared	0.036587	Mean dependent var	11.98476
Adjusted R-squared	-0.014119	S.D. dependent var	7.634337
S.E. of regression	7.688043	Akaike info criterion	7.007602
Sum squared resid	1123.014	Schwarz criterion	7.107081
Log likelihood	-71.57982	Hannan-Quinn criter.	7.029192
F-statistic	0.721551	Durbin-Watson stat	0.638962
Prob(F-statistic)	0.406212		

REFERENCES

Bilby, E. (2012).*EU imposes duties on imports of Chinese organic-coated steel*. Retrieved April 30, 2013, http://www.reuters.com/article/2012/09/19/eu-china-dumping-idUSL5E8KJA7420120919

Changfu, Zh. (2012). *The role of the iron & steel industry in China's future economic development*.Retrieved April 30, 2013, http://www.worldsteel.org/dms/internetDocumentList/downloads/media-centre/06-EN-Changfu-Zhang-CISA/Speech%20at%20the%20%E2%80%9CLCA%20and%20Steel%E2%80%9D%20Seminar-by%20CISA.pdf

China Mining Federation. (2012).*China 2011 coal exports down 22.97% on year at 14.66 million tons*. Retrieved April 30, 2013, http://www.chinamining.org/News/2012-01-12/1326350504d53346.htm

Congressional Research Service. (2010). *China's steel industry and its impact on the United States: Issues for congress* (CRS Publication No. 7-5700, R41421). Washington, DC: U.S. Government Printing Office.

Economist, The. (2013). *China's economy: Perverse advantage*. Retrieved April 30, 2013, http://www.economist.com/news/finance-and-economics/21576680-new-book-lays-out-scale-chinas-industrial-subsidies-perverse-advantage

Elliot, M. (Editor)(2013). *Global steel 2013: A new world, a new strategy*. London: Ernst&Young.

EUROFER Market Outlook. (2012). *Economic and Steel Market Outlook 2012-2013: Q4-2012 Report from EUROFER's Economic Committee*. The European Steel Association, November 2012.

Eurofer. (2013). *Economic and steel market outlook 2013-2014: Q2-2013 Report from EUROFER's Economic Committee*. Retrieved April 30, 2013, http://www.eurofer.org/index.php/eng/content/download/387/2316/file/Market%20Report-2013-April.pdf

Europa.eu (2013).*What is the EU doing about climate change?* Retrieved April 30, 2013, http://ec.europa.eu/clima/policies/brief/eu/index_en.htm

Fontanella-Khan, J. (2013).*ArcelorMittal shares boosted by unexpectedly upbeat results*. Retrieved April 30, 2013, http://www.ft.com/intl/cms/s/0/fe09d07c-b93f-11e2-9a9f-00144feabdc0.html#axzz2TkNbI3T3

Friedland, J. (2013). *Economic growth and steel demand impact the world's steelmakers*. Retrieved: April 30, 2013, http://seekingalpha.com/article/1365631-economic-growth-and-steel-demand-impact-the-world-s-steelmakers

General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ). (2008). *General principles for calculation of the comprehensive energy consumption* (Standardization Administration of the People's Republic of China (SAC), GB/T 2589-2008). Beijing: Printing office unknown.

Genet, M. (2012). *EAF and/or BF/BOF: Which route is best for Europe?* Retrieved April 30, 2013, http://www.laplaceconseil.com/LaplaceConseil/htdocs/admin/upload//File/MarcelGenetPlatts1205.pdf

Ghosh, S. (March 1, 2006). Steel consumption and economic growth: Evidence from India. Resources Policy. Volume 31 (2006), pp. 7-11.

Gutierrez, T. (Editor)(2013). China's economy adding to uncertainty.*SBB world steel review, 21 December (Issue 50-11) 2011*. Retrieved April 30, 2013, https://www.steelbb.com/files/Reports/WSR/SBB_WSR_21Dec11_Sample.pdf

Haley, U., C., V. & Haley, G., T. (2008).*Subsidies and the China price*. Retrieved April 30, 2013, http://hbr.org/2008/06/subsidies-and-the-china-price/ar/1

Hasanbeigi, A., Chunxia, Zh., et al. (2011). A comparison of iron and steel production energy use and energy intensity in China and the U.S. *ERNEST ORLANDO LAWRENCE*

BERKELEY NATIONAL LABORATORY, July 2011. Retrieved April 30, 2013, http://china.lbl.gov/sites/china.lbl.gov/files/US_China_Steel_Comparison_Report_EN_19July2011.pdf
Hernandez, V. (2013).*Rito Tinto (RIO) forecasts China's steel demand to hit 1B tonnes in 2030*. Retrieved April 30, 2013, http://au.ibtimes.com/articles/465952/20130509/rio-tinto-forecasts-china-s-yearly-steel.htm#.UZfh9CsmnL4
Hook, L. (2013). *Baosteel chief reports subdued outlook*. Retrieved April 30, 2013, http://www.ft.com/intl/cms/s/0/2454e34c-8741-11e2-9dd7-00144feabdc0.html#axzz2TkNbI3T3
Isover.com (2013).*What is energy efficiency?* Retrieved April 30, 2013, http://www.isover.com/Q-A/Green-facts-energy-efficiency/What-is-energy-efficiency
Kerkhoff, H. J. (2012). *Report given to SBB: Future of EU steel industry at stake: Eurofer*. Retrieved April 30, 2013, http://sbb.com/?PageID=157&article_id=75428
Kerkhoff, H. J. (2013). *Worldsteelshort range outlook*. Retrieved April 30, 2013, http://www.worldsteel.org/media-centre/press-releases/2013/worldsteel-Short-Range-Outlook-April.html
Koons& Lee. (2013). *China coal producers seek new ventures*. Retrieved April 30, 2013, http://online.wsj.com/article/SB10001424127887323361804578386132095659490.html
KPMG China. (2011a). *China's 12th 5-year plan: Iron and steel*. China: KPMG China
KPMG China. (2011b). *China's 12th 5-year plan: Overview*. China: KPMG China
Kynge, J. (2009). *China shakes the world: The rise of a hungry nation*. New York:Phoenix.
Lawrence Berkeley National Laboratory & American Iron and Steel Institute. (2010). *The state-of-the-art clean technologies (SOACT) for steelmaking handbook (2nd edition)* (Prepared for U.S. State Dept. and Dept. of Energy under contracts FS-OES-07- IAA-0007 and DE-AC02-05CH11231 respectively). Printing location and press unknown.
Lawrence Berkeley National Laboratory. (2008a). Table 2B.23.Transportation of Coal and Oil, 1965-2006 (Billion Ton-km).*China energy databook v. 7.0, October 2008*.
Lawrence Berkeley National Laboratory. (2008b).Table 2B.4.Coal Mine Safety: Mining Deaths, 1992-2006. *China energy databook v. 7.0, October 2008*.
Lawrence Berkeley National Laboratory. (2008c).Table 4A.17.2.End-Use Energy Consumption by Source (Shares).*China energy databook v. 7.0, October 2008*.
Lawrence Berkeley National Laboratory. (2008d).Table 4B.11.Energy Intensity per GDP Unit.*China energy databook v. 7.0, October 2008*.
Lawrence Berkeley National Laboratory. (2008e).Table 4B.3.Energy Intensity by Province (Primary Energy Consumption per Unit of GDP).*China energy databook v. 7.0, October 2008*.
Lawrence Berkeley National Laboratory. (2008f).Table 5B.11. Major Appliances. *China energy databook v. 7.0, October 2008*.
Lawrence Berkeley National Laboratory. (2008g).Table 7B.4.Coal and Coke Imports and Exports.*China energy databook v. 7.0, October 2008*.
Lawrence Berkeley National Laboratory. (2008h).Table 9B.3.World Primary Coal Consumption.*China energy databook v. 7.0, October 2008*.
Lawrence Berkeley National Laboratory. (2008i).Table 2A.1.3. Primary Energy Production (Shares).*China energy databook v. 7.0, October 2008*.
Levine, M. D., Price, L., Yowargana, P. et al. (2010).Assessment of China's energy-saving and emission-reduction accomplishments and opportunities during the 11th 5-year plan.*ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY, April 2010*. Retrieved: April 30, 2013, http://china.lbl.gov/publications/assessment-energy-saving-accomplishments-and-opportunities-in-China
Liebman, B. H. (2006 July). Safeguards, China, and the price of steel.Review of World Economics, JSTOR, Vol. 142, No. 2, pp. 354-373.

Marketwatch. (2013). *China's vehicle lets up 4.3%, miss forecast*. Retrieved April 30, 2013, http://www.marketwatch.com/story/chinas-2012-vehicle-sales-up-43-miss-forecast-2013-01-11

Mastny, L. (editor). (2010). Renewable energy and energy efficiency in China: Current status and prospects for 2020. *World Watch Report, 182, Oct. 2010*. Retrieved April 30, 2013, http://www.worldwatch.org/system/files/182%20China%20Energy.pdf

Miller, J., W. (2012). *Global steel industry faces capacity glut*. Retrieved April 30, 2013,http://online.wsj.com/article/SB10001424127887324595904578116761144046732.html

Mohindru, C., M. (2013). *Rio Tinto says China iron ore sales will rise*. Retrieved April 30, 2013, http://online.wsj.com/article/SB10001424127887323744604578470151175790188.html

Morse, R., K. & He, G. (2010 August). The world's greatest coal arbitrage: China's coal import behavior and implication for the global coal market. *Freeman Spongli Institute for International Studies*. Working paper *series* # 94

Muir, H. (2004). *Manhole covers vanish in the night*. Retrieved April 30, 2013, http://www.guardian.co.uk/uk/2004/oct/25/ukcrime.prisonsandprobation

National Development and Reform Commission. (2004). *China medium and long term energy conservation plan*. Retrieved April 30, 2013, http://fourfact.com/images/uploads/China_Energy_Saving_Plan.pdf

Natural Resources Canada. (2013a). *Gigajoule (Gj)*. Retrieved April 30, 2013, http://oee.nrcan.gc.ca/commercial/technical-info/tools/8397

Natural Resources Canada. (2013b). *Gigajoule and energy intensity calculator*. Retrieved April 30, 2013, http://oee.nrcan.gc.ca/commercial/technical-info/tools/gigajoule.cfm

OECD. (2009). *Presentation for the Council Working Party on shipbuilding*.(OECD Steel Committee). Retrieved: April 30, 2013, http://www.oecd.org/sti/ind/43312347.pdf

Oster, Sh. (2008). *China spurs coal price surge*. Retrieved April 30, 2013, http://online.wsj.com/article/SB120275985736359763.html

Rein, Sh. (2012).*The End of Cheap China: Economic and Cultural Trends that will Disrupt the World*. Hoboken, New Jersey: Wiley & Sons.

Reuters. (2013). *BHP responds to China claim of iron ore manipulation*. Retrieved April 30, 2013, http://www.reuters.com/article/2013/03/07/china-ironore-idUSL4N0BZ12420130307

Sedgman, Ph. (2013). *Goldman cuts iron-ore forecast as global demand growth slows*. Retrieved: April 30, 2013, http://www.bloomberg.com/news/2013-03-19/goldman-reduces-iron-ore-forecast-as-global-demand-growth-slows.html

Sinton, J. E., Fridley, D. G. (2000 June). What goes up: recent trends in China's energy consumption. Energy Policy, Vol. 28., Issue 10, pp. 671-687.

Steel Business Briefing. (2009a). *Wugang to commission 3rd coke dry quenching plant*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=63015

Steel Business Briefing. (2009b).*Xingang saves $12m a year from waste gas recycling*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=63015

Steel Business Briefing. (2011). *Taiwan Chain Chon to buy China stainless coil center*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=94662

Steel Business Briefing. (2012a). *30% emission cut 'unthinkable': EU commissioner*. Retrieved April 30, 2012, http://sbb.com/?PageID=157&article_id=109033

Steel Business Briefing. (2012b). *Chart: China domestic (incl. 17% VAT), China export HRC (FOB Shanghai)*. Retrieved April 30, 2013, http://sbb.com/steelprices/flat/

Steel Business Briefing. (2012c). *Chart: N. Europe domestic, S. Europe domestic, Europe import HRC*. Retrieved April 30, 2013, http://sbb.com/steelprices/flat/

Steel Business Briefing. (2012d). *Demand sentiment of European companies improves - TSI survey*. Retrieved April 30, 2013, http://sbb.com/?PageID=157&article_id=115079

Steel Business Briefing. (2012e). *Entry: 'Electrical Steels'*. Retrieved April 30, 2013,

http://sbb.com/steelglossary
Steel Business Briefing. (2012f). *OECD Steel Committee warms on protectionism, over-capacity*. Retrieved April 30, 2013, http://sbb.com/?PageID=157&article_id=114986
Steel Business Briefing. (2012g). *Posco lifts low-priced HRC supply to check Chinese imports*. Retrieved April 30, 2013, http://sbb.com/?PageID=157&article_id=114986
Steel Business Briefing. (2012h). *Special report: Most Chinese mills warn of 2012 losses*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=116656
Steel Business Briefing. (2012i). *US must 'watch out' for growing China capabilities: analyst*. Retrieved April 30, 2013, http://sbb.com/?PageID=157&article_id=114391
Steel Business Briefing. (2012j).*Europe's carbon reduction scheme 'heavy burden' for industry*.Retrieved April 30, 2013, http://sbb.com/?PageID=157&article_id=106360
Steel Business Briefing. (2013a). *China's MIIT affirms six means to tackle overcapacity*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=119347
Steel Business Briefing. (2013b). *Chinese mills struggle with margin squeeze*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=118491
Steel Business Briefing. (2013c). *Good time for steel industry mergers: Miller Mathis*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=118062
Steel Business Briefing. (2013d). *No sign of recovery for coil prices in Northern Europe*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=119618
Steel Business Briefing. (2013e). *Special report: 2013 to be tough for global steel industry*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=119443
Steel Business Briefing. (2013f). *Special report: China's overcapacity worries new leader X*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=116312
Steel Business Briefing. (2013g). *Special report: Japan pitches energy tech to India*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=116907
Steel Business Briefing. (2013h). *Special report: Private mills make 50% of Chinese steel*. Retrieved April 30, 2013. https://www.steelbb.com/?PageID=157&article_id=117828
Steel Business Briefing. (2013i). *Thatcher's legacy: A privatized steel industry*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=118883
Steel Business Briefing. (2013j). *Top Chinese official bangs overcapacity drum; industry deaf?* Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=120262
Steel Business Briefing. (2013k). *Turkey aims to be Europe's largest steel producer in 2023*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=119396
Steel Business Briefing. (2013l). *Under fire, Cromme steps down as ThyssenKrupp chairman*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=117946
Steel Business Briefing. (2013m). *US Steel: Atomic level analysis to benefit steel*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=119031
Steel Business Briefing. (2013n). *World economic growth is uneven, steel markets remain soft*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=119444
Steel Business Briefing. (2013o). *Wugang'sFangchenggang projects show no sign of progress*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=117541
Steel Business Briefing. (2013p). *Beijing sets air pollution goal for major steelmaking areas*. Retrieved April 30, 2013, https://www.steelbb.com/?PageID=157&article_id=118213
Steel Statistical Yearbook 2012. (2012). Brussels, Belgium: Economics Committee, World Steel Association.
Su, Ch. (2012). *Updates on the Chinese steel industry*. Paris: China Iron and Steel Association.
Thompson, M. (2013). *IMF cuts global growth forecast*. Retrieved April 30, 2013, from CNN Money/Economy: http://money.cnn.com/2013/04/16/news/economy/economy-imf/index.html
Tingting, Zh. (2011). *China's coal imports up 31% in 2010*. Retrieved April 30, 2012, http://www.chinadaily.com.cn/business/2011-01/27/content_11926703.htm

World Coal Association. (2011). *Investing in energy infrastructure*. Retrieved April 30, 2013, http://www.worldcoal.org/resources/ecoal-archive/ecoal-current-issue/investing-in-energy-infrastructure/

World Coal Association. (2013).*Coal statistics*. Retrieved April 30, 2013, http://www.worldcoal.org/resources/coal-statistics/

World Steel Association. (2012a). *The white book of steel.*http://www.worldsteel.org/dms/internetDocumentList/press-release-downloads/2013/The-white-book-of-steel/document/The%20white%20book%20of%20steel.pdf

World Steel Association. (2012b). *World Steel in Figures 2012*.(World Steel publication No. 1379-9746). Retrieved: April 30, 2013, http://www.worldsteel.org/dms/internetDocumentList/bookshop/WSIF_2012/document/World%20Steel%20in%20Figures%202012.pdf

Worldwatch.org. (2013).*China calls on the U.S. to join Kyoto Protocol*. Retrieved April 30, 2013, http://www.worldwatch.org/node/144

Worrel, E., Blinde, P. et al. (2010). Energy efficiency improvement and cost saving opportunities for the U.S. iron and steel industry: An ENERGY STAR® guide for energy and plant managers. *ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY: Environmental Energy Technologies Division, October 2012*. Retrieved: April 30, 2013, https://www.energystar.gov/ia/business/industry/Glass-Guide.pdf

Worrell, E., Price, L., Neelis, M. et al. (2008). World best practice energy intensity values for selected industrial sectors. *ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY: Environmental Energy Technologies Division, February 2010*. Retrieved: April 30, 2013, http://ies.lbl.gov/iespubs/LBNL-62806.Rev.2.pdf

Xu, J. (2011). Energy intensity in China's iron and steel sector.*Master thesis in City Planning, submitted to Massachusetts Institute of Technology, June 2011*. Retrieved April 30, 2013, http://hdl.handle.net/1721.1/67246

Yang, Ch. (2013). *Surplus to requirements*. Retrieved April 30, 2013, http://www.globaltimes.cn/content/782957.shtml#.UZ5iuSsmnL4

Yap, C., W. (2013). *China projects modest steel-production growth*. Retrieved April 30, 2013, http://online.wsj.com/article/SB10001424127887324789504578382052619598938.html

Yunyu, F. (2013). *China's steel industry still suffering*. Retrieved April 30, 2013, http://english.people.com.cn/90778/8233223.html

Zacks Equity Research (2013).*Steel industry stock outlook – march 2013*. Retrieved April 30, 2013, http://finance.yahoo.com/news/steel-industry-stock-outlook-march-190018940.html

Zhou, N., Fridley, D. et al. (2011).China's energy and carbon emissions outlook to 2050.*ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY, April 2011*. Retrieved April 30, 2013, http://eaei.lbl.gov/sites/all/files/LBL_4472E_Energy_2050.April_.2011_1.