# Vehicle recalls performance in an emerging market: Evidence from the comparison between China and U.S.



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# Vehicle Recalls Performance in An Emerging Market: Evidence from the Comparison Between China and U.S.

Wen Shi[a], Leng Kaijun[b*], Inneke Van Nieuwenhuyse[bc],

Yucui Liu[d], Xiaohong, Chen[a]

[a]School of Business, Central South University, 410083, Changsha, China

[b]Research Center of Hubei Logistics Development, Hubei University of Economics, 430205, Wuhan, China

[c]UHasselt_Research Group Logistics, Hasselt University, 3590 Hasselt

[d]School of Management, Huazhong University of Science and Technology, 430080, Wuhan, China

**Abstract:** The past decade has witnessed a remarkable growth of automobile sales and production in emerging economies, with China developing into the largest global auto market since 2009. This paper focuses on an important but neglected aspect in these emerging markets, namely, vehicle recalls. The aim of this study is twofold. The first is to show that a significant difference exists in the number and volume of vehicle recalls between the emerging Chinese market and the established US market; the second is to detect whether this difference can be attributed to the initiator level (voluntary versus involuntary recalls) and/or the firm level (organizational ownership structure and nationality of the foreign partner in international joint ventures). To that end, we quantify the recall performance by means of 4 metrics: total number of recall events per annum (NRE), total number of units recalled per annum (NUR), average number of vehicles recalled per event per annum (NRPE), and recall rate (RR); for each of these, we benchmark the US market and assess the relative performance of the investigated market using a bootstrap method. The empirical results indicate that the recall metrics in the Chinese market have underperformed relative to those of the established market. This is extremely pertinent in light of the current "Going Out" policy put forward by the Chinese government, as subpar quality awareness hampers the successful access of Chinese automakers to foreign markets.

**Keywords:** Vehicle recalls; voluntary recalls; mandatory recalls; self-owned brand; joint-venture

# 1 Introduction

In current manufacturing industries, from toy to food to automobile, product quality and product safety are essential. In spite of the constant pursuit of perfection, product defects often remain inevitable due to increasing product complexity, especially in technology products such as automobiles. Vehicle recalls occur when automakers (or government agencies) decide that a car model is not safe, or does not comply with a recognized standard; automakers then offer free repair, in order to eliminate the hazards that endanger drivers and passengers. From the perspective of addressing safety issues, vehicle recall is a good sign (Consumer Reports, 2015); indeed, cars are better and safer than they ever have been made (Worland, 2015). Common causes of vehicle recalls involve wire-triggered fire, defective accelerators, or defective airbag inflators (Shah et al., 2015).

As the BRICS countries (i.e., Brazil, Russia, India, China, and South Africa) are driving growth in global automobile markets[1], the attention to vehicle recalls has shifted from developed nations (Bates et al., 2007; Haunschild and Rhee, 2004) to emerging economies such as China (Beamish and Hari, 2008; Zhao et al., 2013). Despite the attention of media and government (Hongxi and Yongqin, 2014), little effort has been made by academia to study vehicle recalls in emerging markets. Yet, such study is vital, as the automobile sector is currently one of the main drivers of China's emerging economy. The growth of this sector has driven production growth at the level of components, through supply chains that extend throughout other emerging markets. As such, the performance of the automobile sector has significant implications in China as well as in other emerging markets (Zhao et al., 2013).

While vehicle recalls may entail considerable repercussions for automakers, there is growing consensus that recalls signal the *maturity* of a country's automobile industry (Hora et al., 2011; Tribune, 2014). Their widespread nature not only underscores the fact that vehicles are highly complex end products, but also that the industry takes responsibility to protect drivers, passengers and general public (especially so in the case of voluntary recalls). Recall metrics thus signal *quality awareness,* rather than the quality level of the good being sold. Indeed, in mature automobile markets such as the US (Haunschild and Rhee, 2004; Rhee and

[1] Brazil officially ended the worst recession in its history in the second quarter in 2017, and its automotive market shows sign of recovery (https://www.marklines.com/en/report/rep1628_201708).

Haunschild, 2006), UK (Bates et al., 2007), and Japan (Barber and Darrough, 1996), vehicle recalls occur frequently, and have grown into regular events that are accepted by carmakers, regulators, investors and customers as part of the ordinary course of business.

In this research, we investigate the difference in recall performance between the Chinese market and the (established) US market, examining differences at the level of the recall initiator (i.e., voluntary or proactive recalls vs. mandatory or passive recalls) and at the firm level (organizational ownership structure and nationality of the foreign partner in international joint ventures). We focus on these two levels for the following reasons: 1) government scrutiny clearly differs between both economies, so we need to distinguish between voluntary and involuntary recalls to make a fair comparison; 2) in emerging economies (see also Saha and Chattopadhyay, 2015 and Sun and Lee, 2013), the industry largely relies on a specific ownership structure: international joint ventures (IJVs). We define an IJV as an entity/company that is partly owned by a global automaker (GA), while Chinese domestic automakers (CDAs) are owned by a combination of Chinese investors and the (central and local) government. In China, IJVs account for 70% of passenger car sales, vs. approximately 17.5% in the global world market. Including the ownership in the analysis thus may reveal interesting observations, by comparing the recall performance of international joint ventures (IJVs) versus that of Chinese domestic automakers (CDAs) and global automakers (GAs).

Our study involves multiple comparisons on sample data derived from different sources. The samples take the form of time series; as most sample sizes are relatively small and the sample variances are unequal, statistical inference is obtained using a bootstrap-based hypothesis testing procedure (Efron and Tibshirani, 1993; Wilks, 1997; Martin, 2007). Bootstrapping is a versatile statistical tool, well suited for non-parametric testing on sample data with any known or unknown distribution, as it does not require that data are (approximately) normally distributed (Dellino et al., 2012; Martin, 2007).

The contributions of our manuscript are threefold:

(i) To the best of our knowledge, this is the first study to evaluate automobile recall performance in China, proposing a comparative framework that pays attention to ownership structure and the initiator of the recall. The results may offer significant insights for other emerging markets such as Brazil, Russia, India (i.e., the other BRIC countries), which also exhibit remarkable growth in automotive production (Tang, 2009).

(ii) Whereas the current literature tends to focus on the number of recall events (NRE) over a given period of time (e.g., a year), we additionally introduce the *average number of units recalled per event per annum* (NRPE) indicator, to detect differences in the volume of cars being affected per recall event. Automakers may try to minimize recall costs not only by avoiding recalls altogether, but also by limiting recall volumes.

(iii) We provide evidence that the past "Exchange Market for Technology" policy has not been sufficient to bring the Chinese automobile industry to the same maturity level as the main international players, and discuss insights and implications for both government and managers.

In Section 2, we outline the research context and the research questions. Section 3 discusses the related literature, while Section 4 outlines the recall performance metrics. In Section 5, we detail our methodology, including the evaluation framework, the data sources, and the hypothesis testing approach used in this research. Section 6 presents the results; Section 7 provides concluding remarks and issues for further research.

## 2 Automobile industry in China: context and research questions

The automotive industry is considered as one of the most influential business sectors in the world (ACEA, 2016; Cachon and Olivares, 2010). Over the last decade, the Chinese government has proposed a "Ten Industrial Development Plan" to address external and internal needs, adjust economic structure, and further stimulate domestic growth. The automobile sector, which has become one of the main leading industries in China's economy (Tang, 2009), is recognized as the most important industry in this plan (Shi et al., 2014). In line with the economic boom, China has continued to be the world's largest automobile producer and market since it outpaced the US in 2009 (Sperling and Gordon, 2009). Chinese automakers (consisting of international joint ventures and independent domestic automakers) sold 24.6 million motor vehicles in their own market in 2015, accounting for 25% of the world total, while the EU accounted for 16% and the US for 19% (Hirsch, 2015). The Chinese market is expected to grow at an annual rate of 5% over the next decade with sales hitting 30 million vehicles by 2020 (Feng et al., 2015; Sperling and Gordon, 2009). As China becomes a major player in the global auto market, the Chinese government expects to emerge as a major power in this industry over the next decade.

The past “exchange-market-for-technology” policy implemented by the Chinese government allowed Chinese industries to acquire foreign technology and knowledge through venture capital. This has recently changed to a "Going Out" policy, stimulating Chinese companies to invest overseas. In the automobile industry, the former policy stimulated the growth of alliances and international joint ventures (IJVs) between foreign automobile manufacturers and Chinese partners (e.g., SAIC-GM is a 50/50 joint venture between US-based General Motors and China-based SAIC Motor). Such IJVs were established to build a strategic alliance, in view of creating synergies (Kale et al., 2000). Currently, IJVs are dominating the Chinese vehicle sales market (Hongxi and Yongqin, 2014): during 2004 - 2014, they accounted for almost 80% of the vehicle sales in China (see also Table 7).

The “Going Out” policy, on the contrary, encourages Chinese car manufacturers to produce and sell cars globally (Feng et al., 2015). Currently, only a small percent (4.5% in 2011) of the total output of CDAs is exported to other nations, mainly located in South America, Africa, and the Middle East (Canis and Morrison, 2013). While China has built significant vehicle production capacity, led by its strong internal market demand, it still struggles to meet product quality and safety standards in overseas markets, especially those in industrialized countries (Tang, 2008). At the same time, the literature suggests that traditional vehicle superpowers (such as the US, Japan, and Germany) have continuously invested in enhanced product quality and safety (Hora et al., 2011).

Compared to these superpowers, China does not have such a long recall history. The first Chinese vehicle recall regulation “*Provisions on the Administration of Recall of Defective Auto Products*” was stipulated by the State Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) on March 12, 2004, marking the start of the Chinese government’s official involvement in vehicle safety and quality improvement. In 2012, the “*Regulation on the Administration of Recall of Defective Auto Products*” was issued, in order to further strengthen supervision and administration, and to protect personal and property safety. Since the enactment of the

Provision in 2004, China has performed 1,079 recalls for a total of 25.3 million vehicles, surging from 330,000 vehicles in the earliest 13 recalls in 2004 to 5,549,000 vehicles in the 233 recalls that occurred in 2015. Both media and research unceasingly report that China's vehicle recalls hit a record high (CNBC, 2015; Daily, 2010; Zhao et al., 2013). Nearly all of these recalls are voluntary recalls, mandatory recalls are extremely rare in China; only one event could be found over the period 2004-2014, which concerned defective gearbox systems produced by IJVs with Volkswagen as international partner.

As government and automakers are the main initiators of recalls (Haunschild and Rhee, 2004; Rhee and Haunschild, 2006), we formally distinguish between voluntary recalls and mandatory recalls in this research. Typically, voluntary recalls are initiated before any injuries or deaths are reported, while mandatory recalls often occur after a safety hazard has led to injuries or deaths. Obviously, voluntary recalls reflect automakers' pursuit for quality and reliability improvement, while mandatory recalls reflect the government's capability and commitment to monitor, regulate and control vehicle safety.

While advanced markets are typically characterized by sole-proprietorship automakers (such as GM, Ford and Toyota), the current production and sales markets in China are dominated by IJVs. Table 1 gives an overview of the major IJVs currently present in China's automotive sector. The non-Chinese part in an IJV can have at maximum 50% stake; as the typical ownership ratio for IJVs is 50:50, we consider IJVs as an intermediate form between global automakers and a local independent firm. The IJV structure is often used as a factor to distinguish China from the mature markets in the automotive industry (Nam, 2011).

This article starts from the following questions:

(i) Is the vehicle recall performance in the Chinese market at a comparable level with the recall performance in established markets after a decade of execution of the recall policy? Given that recalls signal industry maturity, and China's increasing ambitions in the global automobile industry, this is a very pertinent question.

Next, we probe into the following three issues, in order to facilitate targeted policy making if a remarkable performance gap appears in (i):

**Table 1 Main international joint ventures in China**

| Chinese partner | Global partner | Partner origin | Name of the IJV | Ownership ratio |
|---|---|---|---|---|
| Beijing Group | Hyundai | KOR | Beijing Hyundai | 50:50 |
| | Benz | GER | Beijing Benz | 50:50 |
| Brilliance Group | BMW | GER | BMW Brilliance | 50:50 |
| Changan Group | Suzuki | JPN | Changan Suzuki | 51:49 |
| | Ford | US | Changan Ford | 50:50 |
| Dongfeng Group | Peugeot-Citroën | FRA | Dongfeng Peugeot-Citroën | 50:50 |
| | Nissan | JPN | Zhengzhou Nissan | 50:50 |
| | KIA Motors | KRA | Dongfeng Motor Corporation | 50:50 |
| | Honda | JPN | Dongfeng Honda | 50:50 |
| | Renault | FRA | Dongfeng Renault | 50:50 |
| FAW Group | Volkswagen (VW) | GER | FAW-Volkswagen (FAW-VW) | 51:49 |
| | Toyota | JPN | FAW Toyota | 50:50 |
| GAC Group | Toyota | JPN | GAC Toyota | 50:50 |
| | Honda | JPN | GAC Honda | 50:50 |
| SAIC Group | General Motor (GM) | US | Shanghai General Motor (SGM) | 50:50 |
| | Volkswagen (VW) | GER | SAIC Volkswagen (SV) | 50:50 |

(ii) Are there any similarities or differences in vehicle recall performance between global automakers and Chinese automakers (either IJVs, or CDAs)?

(iii) What are the differences (if any) at the level of the recall initiator?

(iv) Are there any differences in recall performance among the Chinese IJVs depending on the home country of the international partner involved in the IJV?

We choose a mature market as a benchmark; more precisely, we select the US, for the following reasons:

(1) The US has the longest vehicle recall history (starting in 1966 with the National Traffic Motor Vehicle Safety Act) and have established a well-developed recall system that effectively protects consumers, in part by active government intervention in the form of mandatory recalls (if required).

(2) The US and China exhibited comparable automobile sales volumes over the last decade (2004-2014). As automobile sales volumes are highly correlated with the number of units recalled (Bates et al., 2007), this enables a fair comparison between the two countries.

(3) The majority of studies on product recalls, particularly vehicle recalls, focus on the US, distinguishing between voluntary recalls initiated by automakers, and mandatory recalls by NHTSA (Nation Highway and Traffic Safety Administration).

We also need to differentiate between both recall strategies, as mandatory recalls are almost non-existent in China.

(4) The US data are relatively integrated and easy to collect. Vehicle recalls initiated voluntarily or mandatorily by the different automakers, are collected by NHTSA and made available publicly on its website (https://www.nhtsa.gov/recalls).

## 3 Literature review

Table 2 surveys related literature (as from 2000) on product recalls in general (including, but not limited to vehicle recalls). We primarily focused on academic publications on product recalls that employed an empirical approach.

A significant part of the literature has focused on the impact of product recall events on a firm's abnormal return, through the observation of stock market prices (Chen et al., 2009; Michael and Andrew, 2001; Rupp, 2001; Suresh et al., 2004; Zhao et al., 2013). They found that, on the whole, recall events are followed by a remarkable decline in stock price. Other studies focus on how prior product recalls contribute to the future recall performance, using metrics such as the number of units recalled (Beamish and Hari, 2008; Haunschild and Rhee, 2004; Steven et al., 2014) and recall frequency (Kalaignanam et al., 2012). In particular, Haunschild and Rhee (2004) connected organizational learning to product recalls, and quantify learning efficiency by recall rate. Furthermore, indicators such as market share change (Rhee and Haunschild, 2006), future accidents (Kalaignanam et al., 2012), as well as recall cost (Chao et al., 2009; Sezer and Haksöz, 2012) have received attention.

Many of these previous studies have examined the influence of the recall policy; i.e., voluntary (proactive) recalls initiated by manufacturers versus mandatory (reactive) recalls mandated by a federal agency such as NHTSA. Rupp (2001); Rupp and Taylor (2002) investigated the stock market reactions to both manufacturer and government initiated automotive safety recalls, and factors influencing car owners' response to safety recalls. Chen et al. (2009) found, somewhat counterintuitively, that voluntary recalls have a more negative impact on firm value than mandatory recalls. Hora et al. (2011) analyzed the time to recall in a toy supply chain, and examined its relationship with various recall strategies, supply chain position, and source of the defect.

Overall, the automobile sector is quite popular in these recall studies; however, most of the articles focus on developed countries, such as the US and UK. Despite the fact that China has evolved into the world's largest automotive market, to the best of our knowledge, no prior study has yet evaluated any performance indicators for Chinese vehicle recalls. Given the fact that China has become the largest automotive market and India has the potential to be the third largest market by 2021 (International, 2015), research on these markets is of great importance. The results may offer significant insights for other emerging markets such as Brazil, Russia, India (i.e., the other BRIC countries), which also exhibit remarkable growth in automotive production (Tang, 2009).

Furthermore, it should be pointed out that the current article differs from other articles such as Haunschild and Rhee (2004) and Rhee and Haunschild (2006) in research paradigm, as we do not apply empirical modeling (regression) to detect factors that explain recall performance. Rather, the goal of this study is to develop a comparative framework, at three different levels (country, initiator, firm level). These essentially correspond to three research perspectives. Almost all publications that adopt empirical regression models (see Table 2) focus only on one research perspective (i.e., the firm level; see again the table). Those works that consider more than one research perspective, especially taking the country level into account, conduct analyses similar to ours: e.g., Bates et al. (2007) examines patterns and trends in vehicle recalls in the UK between 1992 and 2002, and Beamish and Hari (2008) make comparisons between total toy recalls and recalls of Chinese-made toys using US data for the period 1988-2007. Our paper fits in this stream of research; admittedly, the research paradigm is different from the empirical modeling articles, yet the goal of the article also differs.

**Table 2 Survey of recent literature related to product recalls**

| Reference | Research perspective | Automobile | Market | Performance metric | Factors | Methodology |
|---|---|---|---|---|---|---|
| Michael and Andrew (2001) | Enterprise | — | US | Normal return, abnormal return | Recall initiator | Event study |
| Rupp (2001) | Government, enterprise | × | US | Abnormal return | Recall initiator | Empirical modeling |
| Rupp and Taylor (2002) | Government, enterprise | × | US | Recall initiator | Percentage repaired, hazard rating, automakers; etc. | Empirical modeling |
| Haunschild and Rhee (2004) | Enterprise | × | US | Number of severe recalls | Cumulative production, recall strategy, and generalist/specialist | Empirical modeling |
| Suresh et al. (2004) | Enterprise | × | US | Cumulative abnormal returns | Recall events | Event study |
| Rhee and Haunschild (2006) | Enterprise | × | US | Market share change | Defect type, reputation, substitutability, generalist/specialist | Empirical modeling |
| Bates et al. (2007) | Nation, enterprise | × | U.K. | Recall volume, recall events, recall rate; etc. | Years, different automakers | Linear regression, Correlation analysis |
| Beamish and Hari (2008) | Nation | — | Both US and China | Recall volume | Recall location, defect type, Toy import and recall levels | Comparative analysis |
| Chao et al. (2009) | Enterprise | — | — | Recall cost | Cost sharing, partial cost sharing | Mathematical modelling |
| Chen et al. (2009) | Enterprise | — | US | Abnormal return | Recall strategy | Event study, Empirical modeling |
| Hora et al. (2011) | Enterprise | — | US | Time to recall | Recall strategy, defect types, supply chain player's location | Empirical modeling |
| Sezer and Haksöz (2012) | Enterprise | — | — | Recall cost | Recall time | Mathematical modelling |
| Kalaignanam et al. (2012) | Enterprise | × | US | Future accidents and future recall frequency | Recall volume, shared product assets, and brands with different quality levels | Empirical modeling |
| Zhao et al. (2013) | Enterprise | × | China | Abnormal return | Recall events, recall strategy, industry | Event study, Empirical modeling |
| Steven et al. (2014) | Enterprise | — | US | Recall volume | Firm's outsourcing intensity, concentration of firm's suppliers, supply base | Empirical modeling |
| This article | Nation, government, and enterprise | × | Both US and China | Recall events, recall volume, recall rate; etc. | Recall strategy, different ownership of enterprises, different nationality | Empirical comparative analysis Bootstrap hypothesis testing |

## 4 Recall performance metrics

We identify four metrics to assess recall performance. They are based on annual performance: (1) total number of recall events (NRE), (2) total number of units recalled (NUR), (3) average number of recalled unit per event (NRPE), and (4) recall rate (RR). Except for recall rate, each indicator is further divided into two categories based on recall policy: voluntary (initiated by automakers) or mandatory (mandated by governments).

NRE denotes the total number of recall events that take place in a given year (either by country, or by automaker), and is the most popular indicator in vehicle recall research (Bates et al., 2007; Haunschild and Rhee, 2004; Rhee and Haunschild, 2006; Rupp, 2001; Rupp and Taylor, 2002). Given the consensus that recalls signal the maturity of a country's automobile industry, a larger NRE reflects a higher industry safety standard, and an increase in the efforts and cost an automaker has to pay. Because automotive manufacturers typically build a wide variety of models that may use similar or identical components, an individual recall event frequently involves several models.

NUR is another vital indicator recognized by existing scholars to reflect industry maturity (Bates et al., 2007; Rupp, 2001; Rupp and Taylor, 2002), and refers to the total number of vehicles recalled by a country or an automaker in a given year. Vehicles that are involved in multiple sequential recall events are counted in each event. A large NUR is seen as a positive sign for the improvement of vehicle safety (Honik, 2015); the higher NUR is, the maturer is the automobile market.

Automakers may try to avoid recall costs, either by avoiding (voluntary) recall events as much as possible (which can be quantified by NRE), or by minimizing the number of recalled units in case of a recall event. We propose to evaluate the latter by the average number of recalled units per event per annum (NRPE). The deliberate omission of impacted models or vehicles from a recall event (as Toyota did in the US market in 2009, when it intentionally didn't recall some cars with design failures) is theoretically possible, but may entail high penalties (at least $1.2 billion in Toyota's case, according to the United States Department of Justice (2014)).

Due to a positive association between NUR and sales, we use the recall rate (RR) to measure the relative importance of the number of units recalled. RR is defined as the ratio between the number of units recalled and the total number of vehicles sold in a country or by an automaker, over a specific time period (e.g., a year). A high RR then indicates that the manufacturer is proactive and risk-avoiding, which is particularly true when the RR is largely based on voluntary recalls; see the case of Chinese car manufacturers in the following sections.

# 5. Methodology

## *5.1 Framework and hypotheses*

Our evaluation framework consists of three interrelated levels: the country level, initiator level, and the firm level (see the top row in Figure 1). Each level contains a series of hypotheses in light of the research questions in Section 1.

At the country level (see column 1 in Figure 1), we test if there is a significant difference in the average value of each annual indicator $i$ (where $i = \mathrm{SALE}$, $\mathrm{NRE}$, $\mathrm{NUR}$, $\mathrm{NRPE}$, or $\mathrm{RR}$) between US and China:

$$H_0\colon\ \mu_i^{(\text{CHN-SameSale})} = \mu_i^{(\text{US-SameSale})} \ \text{ vs. } H_1\colon\ \mu_i^{(\text{CHN-SameSale})} \neq \mu_i^{(\text{US-SameSale})}, \qquad \text{(H1)}$$

where the superscript "SameSales" in (H1) refers to the comparison over 2004-2014; indeed, it can be shown that the average yearly automobile sales do not differ significantly between the US and China over this time period (see Subsection 6.1), yet there are significant differences in recall performance.

We next examine these differences by zooming in on the initiator level (second column in Figure 1). We first study whether there is a difference between mandatory and voluntary recall indicators for the US. Subsequently, we examine the difference in performance in voluntary recalls between the US manufacturers and their joint ventures in China. In short, we test the hypotheses below:

$$H_0\colon\ \mu_i^{(\text{US-M})} = \mu_i^{(\text{US-V})} \ \text{ vs. } H_1\colon\ \mu_i^{(\text{US-M})} \neq \mu_i^{(\text{US-V})}, \qquad \text{(H2.1)}$$

$$H_0\colon\ \mu_i^{(\text{CHN-V})} = \mu_i^{(\text{US-V})} \ \text{ vs. } H_1\colon\ \mu_i^{(\text{CHN-V})} \neq \mu_i^{(\text{US-V})}, \qquad \text{(H2.2)}$$

where the superscripts "M" and "V" denote the mandatory and voluntary strategy respectively.

Finally, we focus our attention at the firm level. Because many of the leading automakers in China have an IJV structure with 50:50 ownership ratio, we treat them as an intermediate ownership type between global automakers and CDAs. We examine similarities and disparities in recall performance of IJVs versus CDAs:

$$H_0\colon\ \mu_i^{(\text{IJV})} = \mu_i^{(\text{CDA})} \ \text{ vs. } H_1\colon\ \mu_i^{(\text{IJV})} \neq \mu_i^{(\text{CDA})}, \qquad \text{(H3.1)}$$

where the superscripts IJV and CDA correspond to the group of international joint ventures and the group of Chinese domestic automakers, respectively (Figure 1, column 3 shows the split into the two subgroups). Next, we examine whether there are differences in recall performance among the IJVs depending to the nationality of the global partners:

$$H_0\colon\ \mu_i^{(j)} = \mu_i^{(j')} \text{ vs. } H_1\colon\ \mu_i^{(j)} \neq \mu_i^{(j')};\ j \neq j' \in \{\text{US}, \text{GER}, \text{FRA}, \text{JPN}, \text{KOR}\} \quad \text{(H3.2)}$$

where the superscripts US, GER, FRA, JPN and KOR refer to the United States, Germany, France, Japan and Korea, respectively ($4^{\text{th}}$ column of Figure 1). Finally, we test whether the Chinese IJVs perform at the same level of maturity as their international partner:

$$H_0\colon\ \mu_i^{(\text{GM})} = \mu_i^{(\text{SAIC-GM})}, \ldots, \mu_i^{(\text{KIA})} = \mu_i^{(\text{DF-KIA})} \text{ vs. } \mu_i^{(\text{GM})} \neq \mu_i^{(\text{SAIC-GM})}, \ldots, \mu_i^{(\text{KIA})} \neq \mu_i^{(\text{DF-KIA})}, \quad \text{(H3.3)}$$

The superscripts in (3.3), taking GM and SAIC-GM as an example, denote the global automaker operating in the US and its corresponding IJV in China, respectively (last column of Figure 1; if the foreign automaker has more than 1 IJV in China, all IJVs are considered as 1 group entity).

## *5.2 Sample and data*

Table 3 presents the primary sources of our dataset, which we further complemented with summary statistics of sales and vehicle recalls, and data on each automaker's sales and recalls.

**Table 3 Data sources**

| Country | Classification | Sources | Application | Time range |
|---|---|---|---|---|
| China | Country and initiator level | OICA | Sales | 2004-2015 |
| | | AQSIQ | Recalls | 2004-2015 |
| | Firm level | YICHE and SINA | Sales | 2004-2015 |
| | | AQSIQ | Recalls | 2004-2015 |
| US | Country and initiator level | OICA | Sales | 2004-2014 |
| | | NHTSA | Recalls | 1966-2014 |
| | Firm level | Forbes | Sales | 2004-2014 |
| | | NHTSA | Recalls | 2009-2014 |

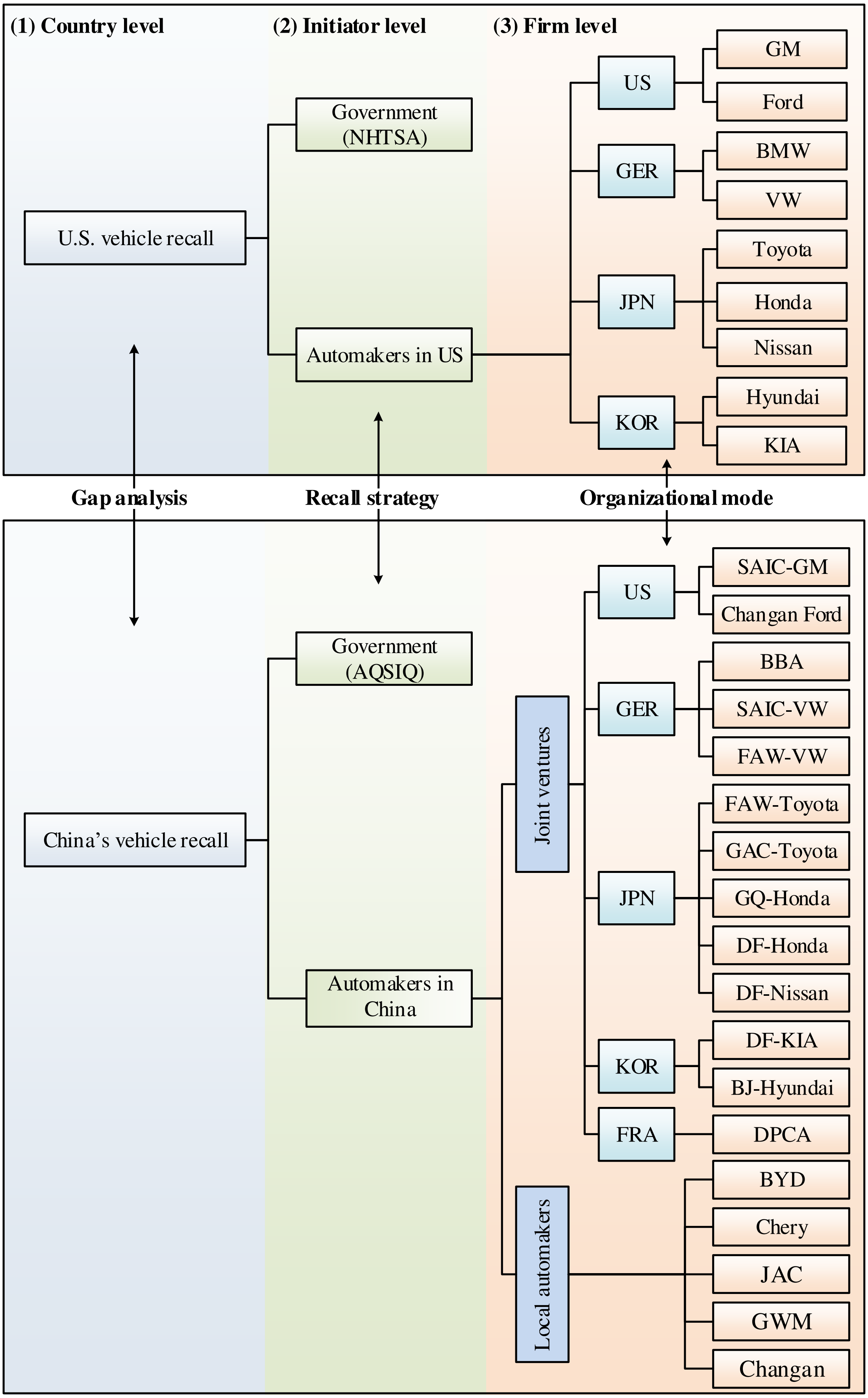



**Figure 1 Evaluation framework for vehicle recall performance**

Sales data of the two countries are relatively easy to obtain. OICA (http://www.oica.net/) is an authoritative automobile website which provides automotive sales statistics for more than 150 nations, from 2004 to present. Sales data for individual automakers are gathered from SINA and YICHE, two influential automobile websites in China. We select the top 20 sellers that account for more than 70% of the Chinese sales market (see column 4 in Figure 1); almost all recalls, either voluntary or mandatory, are tied to them. For a fair comparison, the corresponding international partners of the joint ventures from the Chinese top 20 are selected as US automakers in the set; their sales data are released by Forbes (http://www.forbes.com/).

Recall information for the US was mainly gathered from the NHTSA website (www.nhtsa.gov), which issues an annual recall report related to motor vehicle safety since 1966. We select the sub-report "*Vehicle Recall Summary by Year*", which contains (1) the number of recall events per year, (2) the number of units recalled per year, (3) the number of voluntary and mandatory events per year, and (4) the number of voluntary and mandatory units recalled per year. We also collected data on each individual US automaker; these data were gathered mainly from the "*Yearly vehicle recalls by manufacturers*" report 2009-2014, issued by NHTSA, as well as a variety of other sources, including *Automotive News*, *Wards Automotive Yearbook*, etc.

Aggregate recall data for China were collected from the "*Automotive product safety and recall technology report in China (2014)*" report issued by AQSIQ. Because there are no extant and intact recall data for each individual automaker of the top 20, we tracked each recall announcement released on the Chinese automobile recall website (http://www.qiche365.org.cn/), an official website authorized by AQSIQ. These announcements contain not only the manufacturer, the time span set for the recall, and the volume of vehicles involved, but also details on the brand, model, and Vehicle Identification Number (VIN) of each vehicle involved, the defect description, potential consequences, remedial measures, complaints, and the production period of each batch of vehicles affected.

### *5.3 Comparative analysis using bootstrapping*

The classical *t*- and *F*- statistics that rely heavily on the normal distribution assumption cannot be readily used; even if we assume normality, the populations being tested may exhibit heterogenous variances (known as the Behrens-Fisher problem) which makes the results of these tests unreliable; the same is true for the results of Mann-Whitney-Wilcoxon (MW) tests, see Neuhäuser and Ruxton (2009). This problem becomes particularly severe when the groups have different sample sizes (Zimmerman and Zumbo, 2009). While non-parametric analysis focuses mostly on the median as a measure (MacKinnon, 2009), we are interested in the central tendencies; see the hypotheses (H1) to (H3.3).

As we cannot make any distributional assumptions with regard to our data set, we apply a nonparametric bootstrapping approach. Nonparametric bootstrapping is a sample-resample technique, that is especially useful when the distribution is unknown, or when normal approximations do not hold (Kleijnen, 2015). While many studies have focused on the theoretical development of bootstrapping in statistics, little research has been devoted to bootstrap testing (Martin, 2007) and its applications. In our setting, however, as we observe the indicators over time, the data may take the form of a time series where a trend is present. For that reason, we first correct the data for the observed trend[2], and apply nonparametric bootstrapping to the resulting residuals. In what follows, we provide a detailed description of the approach.

Let $\mathbf{x}_i = (x_{i1}, x_{i2}, ..., x_{in})^{\mathrm{T}}$ and $\mathbf{y}_i = (y_{i1}, y_{i2}, ..., y_{im})^{\mathrm{T}}$ be the data collected on China and US for indicator $i$ (where $i = \mathrm{SALE}$, $\mathrm{NRE}$, $\mathrm{NUR}$, $\mathrm{NRPE}$, and $\mathrm{RR}$) in view of testing hypothesis (H1). The population distributions of $\mathbf{x}_i$ and $\mathbf{y}_i$ are unknown. To use the bootstrap test, we must generate bootstrap samples under the null hypothesis (Efron and Tibshirani, 1993). Toward this end, we use the following conversion process:

$$\tilde{\mathbf{x}}_i = \mathbf{x}_i - \overline{x}_i + \overline{z}_i \quad (1)$$

$$\tilde{\mathbf{y}}_i = \mathbf{y}_i - \overline{y}_i + \overline{z}_i \quad (2)$$

where $\tilde{\mathbf{x}}_i$ and $\tilde{\mathbf{y}}_i$ are the transformed samples based on the original samples $\mathbf{x}_i$ and $\mathbf{y}_i$, and $\overline{z}_i$ is the mean of pooled sample $(\mathbf{x}_i, \mathbf{y}_i)$; i.e.,

$$\overline{z}_i = \left( \sum_{j=1}^{n} x_{ij} + \sum_{j'=1}^{m} y_{ij'} \right) \Big/ (n+m)$$

[2] We thank an anonymous reviewer for this suggestion.

On each of these converted samples (in the following, we focus on $\tilde{\mathbf{x}}_i = (\tilde{x}_{i1}, ..., \tilde{x}_{in})^{\mathrm{T}}$, but the same holds for $\tilde{\mathbf{y}}_i$), we fit a linear function $f_{\tilde{x}_i}$, such that for each time period (year) *j*:

$$\tilde{x}_{ij} = f_{\tilde{x}_i}(j) + \varepsilon_{\tilde{x}_{ij}}, \tag{3}$$

where $\varepsilon_{\tilde{x}_{ij}}$ denotes the residual for indicator *i* in year *j*. Note that the slope (i.e., the trend coefficient) of the linear fit to a converted sample is identical to that of the original data, as each transformed sample is merely the original sample shifted by a constant (see (1)-(2)). Denoting $\boldsymbol{f}_{\tilde{x}_i} = (f_{\tilde{x}_i}(1), ..., f_{\tilde{x}_i}(n))^{\mathrm{T}}$ and $\boldsymbol{\varepsilon}_{\tilde{x}_i} = (\varepsilon_{\tilde{x}_{i1}}, ..., \varepsilon_{\tilde{x}_{in}})^{\mathrm{T}}$, we thus have $\tilde{\mathbf{x}}_i = \boldsymbol{f}_{\tilde{x}_i} + \boldsymbol{\varepsilon}_{\tilde{x}_i}$. We bootstrap the residual vector $\boldsymbol{\varepsilon}_{\tilde{x}_i}$ $B$ times, each time performing $n$ independent draws from $\boldsymbol{\varepsilon}_{\tilde{x}_i}$ with replacement, to obtain bootstrapped residual vectors $\boldsymbol{\varepsilon}^*_{\tilde{x}_i b}$, where the "*" refers to the bootstrapped result and the index $b$ to the number of the bootstrap sample $(b = 1, ..., B)$. Using these bootstrapped residual vectors, we obtain $B$ bootstrapped indicator vectors $\tilde{\mathbf{x}}^*_{ib} = \boldsymbol{f}_{\tilde{x}_i} + \boldsymbol{\varepsilon}^*_{\tilde{x}_i b}$ $(b = 1, ..., B)$. As the same operations are applied to $\tilde{\mathbf{y}}_i$, we have analogous bootstrapped vectors $\tilde{\mathbf{y}}^*_{ib} = \boldsymbol{f}_{\tilde{y}_i} + \boldsymbol{\varepsilon}^*_{\tilde{y}_{ib}}$ $(b = 1, ..., B)$.

We compute the test statistics for the hypothesis:

$$t^*_{ib} = \frac{\bar{\tilde{x}}^*_{ib} - \bar{\tilde{y}}^*_{ib}}{\sqrt{\tilde{S}(x)^{2*}_{ib}/n + \tilde{S}(y)^{2*}_{ib}/m}}, \quad b = 1, ..., B \tag{4}$$

and obtain bootstrap estimates $t^*_{i1}, ..., t^*_{iB}$. In this study, we select $B = 5000$, as a small $B$ may result in a loss of statistical power (MacKinnon, 2009).

Let subscript $(b)$ be the $b$th ordered value with $b = 1, ..., B$. We sort these estimates in ascending order $(t^*_{i(1)} \leqslant \cdots \leqslant t^*_{i(B)})$, so that the empirical density function (EDF) of $t^*_i$ puts probability $1/B$ on each $t^*_{ib}$. Since we do not assume that the test statistic $t_i$ is symmetrically distributed around zero, we follow MacKinnon (2009) and use the *equal-tail bootstrap P-value*

$$\hat{p}^*_i = 2\min\left\{\frac{1}{B}\sum_{b=1}^{B} I(t^*_{ib} \leqslant t_{i0}),\ \frac{1}{B}\sum_{b=1}^{B} I(t^*_{ib} > t_{i0})\right\}, \tag{5}$$

where $I(\cdot)$ is an indicator function that equals 1 if the argument is true, and 0 otherwise, and $t_{i0}$ denots the original test statistic. We reject the hypothesis that there is no difference between the two countries in recall indicator $i$ if $\hat{p}_i^*$ is less than the specified significance level, say $\alpha$.

We summarize the procedure in Figure 2; For ease of notation, we leave out the indicator index *i*. The algorithm was implemented in MATLAB.

**Initialization:** Specify the pre-determined significance level $\alpha$.

**Step 1**: Pool $\mathbf{x}$ and $\mathbf{y}$ together to form a combined sample, $\mathbf{z} = (x_1, \ldots, x_n, y_1, \ldots, y_m)^{\mathrm{T}}$, where $\mathbf{x} = (x_1, x_2, \ldots, x_n)^{\mathrm{T}}$ and $\mathbf{y} = (y_1, y_2, \ldots, y_m)^{\mathrm{T}}$ are the two sets of collected data; e.g., $\mathbf{x}$ and $\mathbf{y}$ are the NRE for US and China, respectively.

**Step 2**: Convert original samples $\mathbf{x}$ and $\mathbf{y}$ to $\tilde{\mathbf{x}}$ and $\tilde{\mathbf{y}}$, using conversion equations $\tilde{\mathbf{x}} = \mathbf{x} - \overline{x} + \overline{z}$ and $\tilde{\mathbf{y}} = \mathbf{y} - \overline{y} + \overline{z}$, respectively, where $\overline{x}$, $\overline{y}$, and $\overline{z}$ are the means of $\mathbf{x}$, $\mathbf{y}$, and $\mathbf{z}$.

**Step 3:** Fit a linear function for $\tilde{\mathbf{x}}$ and $\tilde{\mathbf{y}}$, respectively; based on the model, calculate residuals $(\boldsymbol{\varepsilon}_{\tilde{x}}, \boldsymbol{\varepsilon}_{\tilde{y}})$, and form $B$ bootstrap residual samples $(\boldsymbol{\varepsilon}^*_{\tilde{x}_i b}, \boldsymbol{\varepsilon}^*_{\tilde{y}_i b})$ $(b = 1, \ldots, B)$ by sampling independently with replacement

**Step 4:** Form $B$ bootstrap data sets $(\tilde{\mathbf{x}}^*_b, \tilde{\mathbf{y}}^*_b)$ using $(\boldsymbol{\varepsilon}^*_{\tilde{x}_i b}, \boldsymbol{\varepsilon}^*_{\tilde{y}_i b})$.

**Step 5:** For set $(\mathbf{x}^*_b, \mathbf{y}^*_b)$, calculate $t^*_b = \dfrac{\overline{\tilde{x}}^*_b - \overline{\tilde{y}}^*_b}{\sqrt{\tilde{S}(x)^{2*}_b/n + \tilde{S}(y)^{2*}_b/m}}$, $b = 1, \ldots, B$.

**Step 6:** Calculate $\hat{p}* = 2\min\left(\sum_{b=1}^{B} I(t^*_b \leqslant t_0) \Big/ B,\ \sum_{b=1}^{B} I(t^*_b > t_0) \Big/ B\right)$, where $\hat{p}*$ is the marginal significance level of $t^*_b$; $I(\cdot)$ is an indicator function, which is equal to 1 if the argument in the bracket is true, and 0 otherwise.

**Step 6:** If $\hat{p}* \leqslant \alpha$, reject the null hypothesis; otherwise, do not reject it.

**End**

**Figure 2 Bootstrap hypothesis testing algorithm**

# 6. Results and discussion

In this section, we answer the research questions proposed in Section 2. We start by comparing the overall vehicle recalls in China and the US in Section 6.1. The difference between voluntary and mandatory strategies is studied in Section 6.2. In Section 6.3, we will discuss several factors that contribute to the number of vehicle recalls at the enterprise level.

## *6.1 Difference in recall performance at country level*

As mentioned before, US regulators track recalls since 1966, while China started tracking in 2004. Our analysis thus focuses on the overlap period of the two countries (i.e., 2004-2014). Because of the positive association between sales volumes and recall indicators such as NUR (Bates et al., 2007), we conduct a separate analysis for the sales volume over this period, at a significance level of 0.05. The results are reported in Table 4. As evident from the table, the bootstrap test reveals that there is no reason to reject the null hypothesis, stating that the average yearly sales volumes over this period are equal for both countries. One may note from the data that the mean of SALE (= 1365.7) for China is slightly different from the mean for the US (= 1476.4), whereas the standard deviation of SALE exhibits a larger difference (i.e., 667.0 and 245.4, respectively). This is because an emerging market such as China typically exhibits growth in automobile sales, while sales volumes in established markets such as the US tend to remain more stable. This can also be observed from Figure 3, which shows the sales data for both countries with the corresponding trend lines. The trend coefficient corresponding to the US data is actually not significantly different from zero (see Table 4); yet, the sales trend in China is steeply increasing.

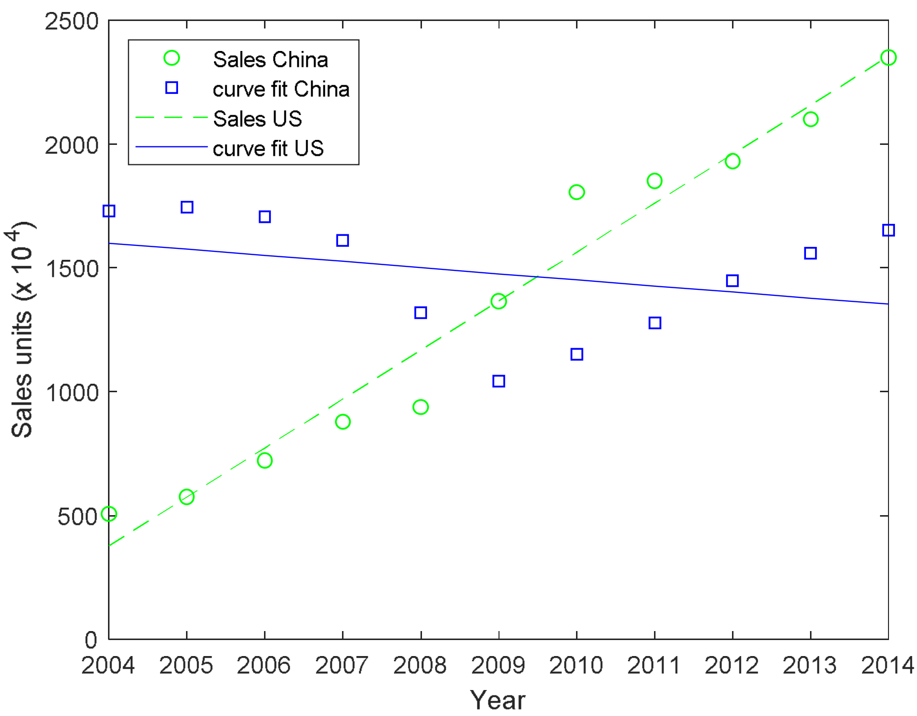



**Figure 3 Automobile sales in the US versus China, in the period 2004-2014, with fitted trend lines**

Yet, Table 4 reveals that the *p*-values for all recall indicators are considerably below $\alpha = 0.05$; there is thus substantial evidence that recall performance differs significantly between China and the US. Although China has grown into the largest automobile market, it is lagging considerably in recall performance when compared to the US (for instance, $\mathrm{NRE}_{\mathrm{USA}}$ attains on average 607.3 per year, which is 7.87 times higher than $\mathrm{NRE}_{\mathrm{CHN}} = 77.2$; $\mathrm{NUR}_{\mathrm{US}}$ is even more than 12.09 times higher than $\mathrm{NUR}_{\mathrm{CHN}}$). Yet, the results for the trend coefficient show that all recall indicators in China show a significantly positive trend, whereas the trend for the US indicators is essentially flat. China is thus clearly improving, and the lagging performance on the average indicators is thus likely a consequence of its shorter recall history. The proposed testing method reaches conclusion for the various indicators listed in the first column of the table.

**Table 4 Comparisons of recall indicators (2004-2014;** $\alpha = 0.05$ **)**

| Ind. | CY | Mean | SD | Trend (slope)[1] | *B*-test |
|---|---|---|---|---|---|
| SALE | CHN | 1365.7 | 667.0 | **197.7** | *B*=5000 |
| (×104) | US | 1476.4 | 245.4 | -24.8 | *p*=0.1428 |
| NRE | CHN | 77.2 | 54.4 | **15.3** | *B*=5000 |
| | US | 607.3 | 87.5 | 14.2 | ***p*=0.0000** |
| NUR | CHN | 180.6 | 187.8 | **50.6** | *B*=5000 |
| (×104) | US | 2184.6 | 1505.0 | 186.1 | ***p*=0.0000** |
| NRPE | CHN | 2.0 | 1.0 | **0.20** | *B*=5000 |
| (×104) | US | 3.5 | 1.8 | 0.13 | ***p*=0.0056** |
| RR | CHN | 0.1 | 0.1 | **0.02** | *B*=5000 |
| | US | 1.5 | 0.9 | 0.13 | ***p*=0.0000** |

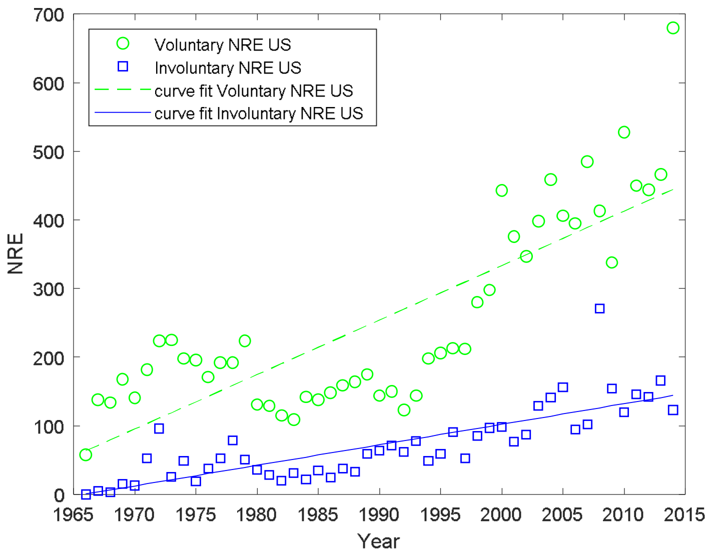
1 Estimated trend coefficients that are shown in **bold** are significantly different from zero (confidence level = 95%).

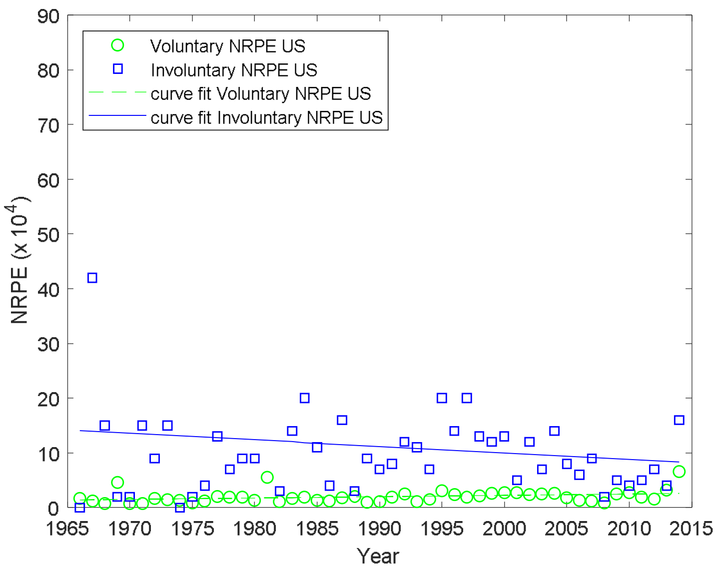
### *6.2 Initiator level*

Our next aim is to identify possible differences at the initiator level. As recalls are rarely mandatory in China (Zhao et al., 2013), this section compares the voluntary (V) recall performance in China and the US, as well as the voluntary (V) and mandatory (IV) recall performance within the US. In the literature, mandatory recalls are considered to mirror national emphasis on vehicle safety standards, while voluntary recalls signal the automakers' willingness to improve product quality and avoid safety hazards (Haunschild and Rhee, 2004; Rhee and Haunschild, 2006).

#### 6.2.1 Voluntary vs. mandatory recalls within the US

Figure 4 (upper plot) displays the US V-NRE and IV-NRE from 1966 to 2014, along with their fitted trend lines. Both indicators have a significantly increasing trend (see Table 5), and show significantly different means over the observed period. Clearly, V-NRE is higher than IV-NRE. Yet, the IV-NRPE is significantly higher than the V-NRPE (see the bootstrap results in Table 5, and the middle pane of Figure 4); while the trend in V-NRPE is slightly increasing, the trend for IV-NRPE is not significant. The resulting average V-NUR and average IV-NUR (bottom panel of Figure 4) do not significantly differ over the observed period; yet, both indicators show a significantly positive trend (see Table 5). While IV-NUR in general exceeded V-NUR in absolute numbers until 2009, this appears to have changed since 2010, with V-NUR in general exceeding IV-NUR.



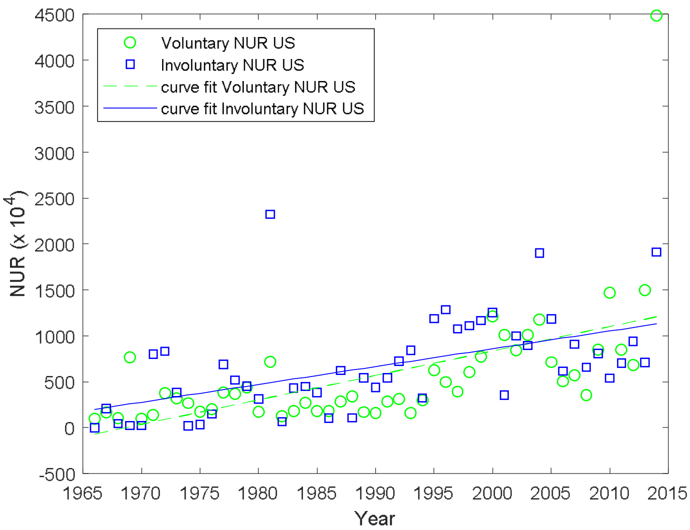



**Figure 4 Comparisons between voluntary and mandatory recalls within the US: NRE (top pane), NRPE (middle pane) and NUR (bottom pane)**

**Table 5 Comparative results US voluntary and mandatory recalls** ($\alpha = 0.05$)

| Indicators | Mean | SD | Trend (slope)[1] | *B*-test |
|---|---|---|---|---|
| V-NRE | 254.1 | 139.8 | **7.93** | *B=5000* |
| IV-NRE | 72.3 | 53.30 | **2.99** | ***p*=0.0000** |
| V-NUR | 568.8 | 676.0 | **26.59** | *B=5000* |
| IV-NUR | 665.4 | 516.6 | **19.37** | *p*=0.4010 |
| V-NRPE | 2.0 | 1.1 | **0.02** | *B=5000* |
| IV-NRPE | 11.1 | 12.6 | -0.12 | ***p*=0.0000** |

1 Estimated trend coefficients that are shown in **bold** are significantly different from zero (confidence level = 95%).

The results suggest that the vast majority of recall events stems from the willingness of automakers themselves. Excluding other factors such as corporate social responsibility factors (Siegel and Vitaliano, 2007), automakers might actually have an incentive to adopt a timely voluntary recall strategy, as a mandatory recall might involve higher costs. Forgoing a *voluntary* recall can indeed lead to heavy fines, exposure to consumer lawsuits, and even sales damage caused by the following mandatory recall: e.g., Toyota has paid over $66 million in fines since 2010, due to a lack of timely voluntary recalls (Wilson, 2013). The work by Haunschild and Rhee (2004) has confirmed, based on recall data for automakers in the US market over the period 1966-1999, that prior voluntary recalls in the car sector indeed reduce subsequent involuntary recalls.

Note that the desirability of voluntary recalls over involuntary recalls can differ across sectors, and according to the performance goal that is being studied: e.g., Chen et al. (2009) and Hora et al. (2011) found that voluntary recalls have a more negative impact on firms' financial value than mandatory recalls in the consumer products an toy sectors; thus, a firm should have an incentive to *avoid* voluntary recalls.

The findings of Haunschild and Rhee (2004) also suggest that the *lack of mandatory recalls* (or more specifically, lack of strict laws and heavy fines) plays a double role in the perceived gap in recall performance between the US and China. Loose government scrutiny does not only lead to lower (or non-existent) involuntary recalls; it may also mitigate the motivation of automakers to deal with potential safety problems, which eventually decreases voluntary recalls. As an example, the federal TREAD Act passed in 2000 in the US requires that automakers actively identify potential problems and promptly notify the NHTSA, while before the Act, they were only required to issue a recall when a consumer reported a problem. Moreover, the US has doubled the maximum fine for mandatory recalls (from $17.4 million to a maximum of $35 million per recall incident), which undoubtedly provides an even greater incentive to issue voluntary recalls.

#### 6.2.2 Voluntary recalls in China vs. voluntary recalls in the US

The comparison results for voluntary recalls are summarized in Table 6. We can see that the two markets exhibit significant differences in NRE and NUR, while there is no significant difference in NRPE. This indicates that there is a substantial difference between the two countries in the propensity to launch a voluntary recall; yet, automakers in the two markets exhibit a similar attitude once they have made the decision to launch a recall. We shall elaborate on this issue in the next subsection. Table 6 also indicates that the time trend for the voluntary recall indicators in the US is not significant, while China clearly shows a significantly positive trend for all three indicators.

**Table 6 Comparisons of voluntary recall indicators (2004-2014; $\alpha = 0.05$)**

| Ind. | Type | Mean | SD | Trend (slope)[1] | $B$-test |
|---|---|---|---|---|---|
| NRE | CHN | 77.2 | 54.4 | **13.97** | $B=5000$ |
| | US | 460.4 | 88.5 | 15.27 | ***p=0.0000*** |
| NUR ($\times 10^4$) | CHN | 180.6 | 187.8 | **50.61** | $B=5000$ |
| | US | 1195.7 | 1152.5 | 198.8 | ***p=0.0004*** |

| | | | | | |
|---|---|---|---|---|---|
| NRPE ($\times 10^4$) | CHN | 2.0 | 1.0 | **0.20** | *B=5000* |
| | US | 1.6 | 26.2 | 0.27 | *p*=0.3600 |
| RR | CHN | 0.1 | 0.1 | 0.1 | *B=5000* |
| | US | 0.8 | 0.7 | 0.0 | ***p=0.0008*** |

[1] Estimated trend coefficients that are shown in **bold** are significantly different from zero (confidence level = 95%).

### *6.3 Firm level*

In this section, we focus only on recall performance at the firm level; i.e., voluntary recalls initiated by *automakers*.

Table 7 lists the Chinese top 20 automakers (in terms of sales volumes over the period 2004 -2015). Sixty-five percent of them have an IJV structure, and the top five IJVs (i.e., SAIC-GM, SVW, FAW-VW, Beijing Hyundai, and Dongfeng Nissan) account for approximately half of the total sales in China. Furthermore, IJVs account for over 85 percent of the total NRE, and over 89 percent of NUR of the top-20. Among CDAs, BYD has not even issued a single recall announcement; in contrast, GWM has issued the maximum number of recall events.

**Table 7 Recall indicators of Chinese top 20 automakers (2004-2015)**

| Automaker | Type | Global partner | Country of partner | Total | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Sales ($\times 10^4$) | NRE | NUR ($\times 10^4$) | NRPE ($\times 10^4$) | RR |
| SAIC-GM | IJV | General Motor | US | 1119.0 | 21 | 244 | 11.6 | 21.8% |
| Changan Ford | IJV | Ford | US | 427.7 | 20 | 113 | 5.6 | 26.4% |
| SVW | IJV | Volkswagen | GER | 1085.3 | 7 | 65 | 9.2 | 6.0% |
| FAW-VW | IJV | Volkswagen | GER | 1020.1 | 13 | 168 | 12.9 | 16.5% |
| BBA | IJV | BMW | GER | 149.0 | 16 | 56 | 3.5 | 37.3% |
| DPCA | IJV | Peugeot-Citroën | FRA | 475.3 | 15 | 51 | 3.4 | 10.6% |
| FAW Toyota | IJV | Toyota | JPN | 475.3 | 25 | 252 | 10.1 | 53.1% |
| GAC Toyota | IJV | Toyota | JPN | 353.3 | 9 | 151 | 16.7 | 42.6% |
| Guangqi Honda | IJV | Honda | JPN | 410.0 | 15 | 292 | 19.5 | 71.3% |
| Dongfeng Honda | IJV | Honda | JPN | 232.3 | 13 | 123 | 9.4 | 52.8% |
| Dongfeng Nissan | IJV | Nissan | JPN | 665.5 | 17 | 82 | 4.8 | 12.3% |
| Changan Suzuki | IJV | Suzuki | JPN | 169.4 | 4 | 54 | 13.4 | 31.7% |
| Beijing Hyundai | IJV | Hyundai | KOR | 727.4 | 10 | 48 | 4.8 | 6.6% |
| Dongfeng Yueda Kia | IJV | KIA | KOR | 357.0 | 5 | 13 | 2.6 | 3.6% |
| BYD | CDA | — | — | 358.5 | 0 | 0.0 | 0.0 | 0.0% |
| Chery | CDA | — | — | 502.5 | 7 | 88 | 12.6 | 17.5% |
| Geely | CDA | — | — | 400.7 | 5 | 43 | 8.6 | 10.7% |
| JAC | CDA | — | — | 167.8 | 2 | 33 | 16.3 | 19.4% |
| GWM | CDA | — | — | 426.5 | 11 | 17 | 1.6 | 4.1% |
| Changan | CDA | — | — | 309.0 | 7 | 25 | 3.5 | 7.9% |
| Average | — | — | — | 491.6 | 11.1 | 96.0 | 8.5 | 22.6% |

Note: IJV and CDA refer to international joint venture and Chinese domestic automaker, respectively.

#### 6.3.1 Comparing independent automakers and joint ventures

Table 8 reports comparative analysis results of sales and recall performance, for IJVs and CDAs. The results from the bootstrap test reveal that the yearly average sales volume for IJVs ($SALE_{IJV}$) differs significantly from that of CDAs ($SALE_{CDA}$). As for the recall indicators, NRPE is the only indicator for which there is no indication that IJVs differ from CDAs; for the rest of the indicators, however, we conclude that IJVs on average outperform CDAs.

IJVs are more aggressive in issuing recall events than CDAs (as evident from the results for NRE); this eventually contributes to the substantial difference in the number of recalled vehicles (NUR). The smaller number of (voluntary) recalls of CDAs is not likely to indicate higher quality; instead, the quality of Chinese brands is known to be much lower than that of international competitors (Bloomberg, 2015; McKinsey & Company, 2015). The lack of voluntary recalls initiated by independent automakers thus helps to explain the difference in NRE and NUR between the US and China. The trend coefficients for all recall indicators are significantly positive, both for IJVs and CDAs; both types of firms are thus making steps forward in terms of quality and safety commitment. IJVs in general proceed at a faster pace than CDAs, except for RR, where both firm types have equal time trend.

**Table 8 Comparative analysis of sales and recall indicators for Chinese IJVs and CDAs (2004-2015)**

| Indicators | Type | Mean | SD | Trend (slope) [1] | *B-test* |
|---|---|---|---|---|---|
| SALE ($\times 10^4$) | IJV | 45.6 | 25.6 | **7.00** | *B=5000* |
| | CDA | 29.5 | 17.8 | **4.84** | ***p*=0.000** |
| NRE | IJV | 1.2 | 0.8 | **0.20** | *B=5000* |
| | CDA | 0.4 | 0.5 | **0.11** | ***p*=0.0000** |
| NUR ($\times 10^4$) | IJV | 9.9 | 9.2 | **2.12** | *B=5000* |
| | CDA | 3.2 | 5.1 | **1.09** | ***p*=0.0000** |
| NRPE ($\times 10^4$) | IJV | 4.6 | 3.8 | **0.82** | *B=5000* |
| | CDA | 3.3 | 7.0 | **1.28** | *p*=0.4752 |
| RR | IJV | 23.3% | 18.1% | **0.03** | *B=5000* |
| | CDA | 8.0% | 11.6% | **0.03** | ***p*=0.0036** |

[1] Estimated trend coefficients that are shown in **bold** are significantly different from zero (confidence level = 95%)

### 6.3.2 Comparing IJVs based on nationality of global partner

Each IJV in Table 7 represents a form of alliance between a Chinese automaker and a global automobile company from an industrialized country, which promises to have a direct impact on its Chinese partner's corporate culture, corporate values, and competitive quality standards. Thus, IJVs may vary greatly in recall performance due to the difference in national background of their global partners. Japanese automakers such as Toyota, for instance, tend to be renowned for their focus on lower inventory, lower cost, and superior quality and customer service (Bernegger and Webster, 2014; Cachon and Olivares, 2010).

Table 9 reports the results for sales and recall indicators of IJVs, depending on the home country of their global partner. These countries include the US, Germany, France, Japan and Korea. As the bootstrap test in Section 5.3 is developed for two samples, we sequentially select two countries out of our set of five, and apply the algorithm. We eventually obtain a $5 \times 5$ symmetric matrix of $p$-values.

We use the initial letter of a nation in superscript to represent that the indicator corresponding to this nation is significantly larger than that of the other nation being considered. As evident from the table, IJVs with an American or German partner show significantly larger sales volumes then those with French, Japanese or Korean partners. Indeed, the two US-based IJVs (i.e., SAIC-G and Changan Ford) together with the three GER-based IJVs (i.e., SVW, FAW-VW, and BBA) account for almost 50% of sales in the Chinese auto market. While the sales volumes for all IJVs, independent of nationality, show a significant upward trend, the volumes of the US- and GER-based IJVs grow at the fastest pace.

The US-based IJVs also have a significantly higher NRE (on average, 2 recalls per year over the observed time period) than IJVs with partners from other countries. Additionally, the US-based IJVs also consistently outperform the French and Korean IJVs, on all remaining indicators (NUR, NRPE, and RR). Except for NRE, there is no significant difference between American and German IJVs; yet, as evident from the results, the American IJVs are actually outperformed by the Japanese IJVs with regard to RR. As shown, the Japanese IJVs are actually superior on RR compared to all other IJVs.

When observing the results for the non-US based IJVs, it is evident that the GER-based IJVs exhibit a recall performance that is noncompliant with their sales: with a sales figure representing about 30% of the Chinese mainland market, they do not show superior performance in the recall indicators when compared to French, Japanese or Korean IJVs; as mentioned above, they are even significantly outperformed by the Japanese on RR.

While all IJVs show a significant upward trend in sales, the trend in RR is essentially flat. Only US- and JPN-based IJVs show a significant upward trend in NUR. The strong trend in NUR for US-based IJVs follows from a significant upward trend both in NRE and NRPE; the trend in NUR for the JPN-based IJVs is more moderate, and only stems from a significant upward trend in NRE.

**Table 9 Recall performance of IJVs, depending on the home country of their international partner (2004-2015)**

| | | | | Global Partner | | | | |
|---|---|---|---|---|---|---|---|---|
| Sales (×$10^4$) | Mean | SD | Trend[1] | US | GER | FRA | JPN | KOR |
| US | 64.6 | 41.5 | **11.29** | — | 0.7772 | ***0.0000***$^{U}$ | ***0.0000***$^{U}$ | ***0.0000***$^{U}$ |
| GER | 63.7 | 39.3 | **10.66** | 0.8040 | — | ***0.0000***$^{G}$ | ***0.0000***$^{G}$ | ***0.0000***$^{G}$ |
| FRA | 39.6 | 26.8 | **6.72** | ***0.0000***$^{U}$ | ***0.0000***$^{G}$ | — | ***0.0336***$^{F}$ | 0.1036 |
| JPN | 31.8 | 12.9 | **3.51** | ***0.0000***$^{U}$ | ***0.0000***$^{G}$ | ***0.0336***$^{F}$ | — | 0.1148 |
| KOR | 45.1 | 28.7 | **7.78** | ***0.0000***$^{U}$ | ***0.0000***$^{G}$ | 0.1036 | 0.1148 | — |
| NRE | Mean | SD | Trend[1] | US | GER | FRA | JPN | KOR |
| US | 2.0 | 1.5 | **0.37** | — | ***0.0016***$^{U}$ | ***0.0184***$^{U}$ | ***0.0000***$^{U}$ | ***0.0000***$^{U}$ |
| GER | 1.0 | 1.2 | **0.24** | ***0.0016***$^{U}$ | — | 0.4688 | 0.5000 | 0.2388 |
| FRA | 1.3 | 1.0 | 0.08 | ***0.0184***$^{U}$ | 0.4688 | — | 0.7608 | 0.1044 |
| JPN | 1.2 | 0.7 | **0.17** | ***0.0000***$^{U}$ | 0.5000 | 0.7608 | — | 0.1000 |
| KOR | 0.6 | 0.9 | 0.12 | ***0.0000***$^{U}$ | 0.2388 | 0.1044 | 0.1000 | — |
| NUR (×$10^4$) | Mean | SD | Trend[1] | US | GER | FRA | JPN | KOR |
| US | 15.3 | 22.7 | **4.20** | — | 0.1944 | ***0.0080***$^{U}$ | 0.5876 | ***0.0092***$^{U}$ |
| GER | 7.5 | 16.0 | 2.39 | 0.1944 | — | 0.1876 | 0.2480 | 0.2096 |
| FRA | 2.5 | 2.8 | 0.31 | ***0.0080***$^{U}$ | 0.1876 | — | ***0.0000***$^{J}$ | 0.9656 |
| JPN | 12.9 | 11.4 | **2.16** | 0.5876 | 0.2480 | ***0.0000***$^{J}$ | — | ***0.0000***$^{J}$ |
| KOR | 2.5 | 4.2 | 0.43 | ***0.0092***$^{U}$ | 0.2096 | 0.9656 | ***0.0000***$^{J}$ | — |
| NRPE (×$10^4$) | Mean | SD | Trend[1] | US | GER | FRA | JPN | KOR |
| US | 5.6 | 6.2 | **1.33** | — | 0.2296 | ***0.0040***$^{U}$ | 0.0672 | ***0.0028***$^{U}$ |
| GER | 3.3 | 6.7 | 1.03 | 0.2364 | — | 0.3000 | 0.7132 | 0.2892 |
| FRA | 1.6 | 1.9 | 0.16 | ***0.0040***$^{U}$ | 0.3000 | — | 0.3712 | 0.9400 |
| JPN | 2.6 | 4.1 | 0.33 | 0.0672 | 0.7132 | 0.3712 | — | 0.9240 |
| KOR | 1.5 | 2.1 | 0.14 | ***0.0028***$^{U}$ | 0.2892 | 0.9400 | 0.9240 | — |
| RR | Mean | SD | Trend[1] | US | GER | FRA | JPN | KOR |
| US | 0.2 | 0.2 | 0.03 | — | 0.1200 | ***0.0124***$^{U}$ | ***0.0320***$^{J}$ | ***0.0084***$^{U}$ |
| GER | 0.1 | 0.2 | 0.03 | 0.1328 | — | 0.4476 | ***0.0024***$^{J}$ | 0.2440 |
| FRA | 0.1 | 0.1 | 0.00 | ***0.0124***$^{U}$ | 0.4476 | — | ***0.0004***$^{J}$ | 0.5000 |
| JPN | 0.4 | 0.4 | 0.05 | ***0.0320***$^{U}$ | ***0.0024***$^{J}$ | ***0.0004***$^{J}$ | — | ***0.0004***$^{J}$ |
| KOR | 0.0 | 0.1 | 0.00 | ***0.0084***$^{U}$ | 0.2440 | 0.5000 | ***0.0004***$^{J}$ | — |

[1] Estimated trend coefficients that are shown in **bold** are significantly different from zero (confidence level = 95%).

#### 6.3.3 Comparing IJVs with their international partners

In this section, we test for differences in the voluntary recall performance of each global automaker (based on US data) and its corresponding IJV(s) (in China). For GAs that have multiple Chinese partners and establish different IJVs (such as Toyota, Honda, and Volkswagen), we merge the corresponding data of its IJVs. Table 10 shows the results. We use the superscript "C" to indicate that the indicator of the IJV in the Chinese market has a significantly larger value than the one of the corresponding GA in US market, and the superscript "U" otherwise.

Apart from Hyundai-KIA[3], the results show that there are significant differences between the sales volume of the GA in the US market, and its IJVs in the Chinese market. For GM, Honda and VW, the sales obtained through their Chinese IJVs exceeds their GA sales in the US (currently, China is even the largest market for both GM and VW). In terms of sales volume, Toyota is the top automaker in the US; in China, SAIC-GM, SAIC-VW, and FAW-VW are currently the best performing IJVs based on sales.

For each GA, the NRE in the US market is significantly higher than the NRE of its IJVs in the Chinese market; the NRPE, though, shows no significant differences. Consequently, the results for NUR are mixed. The RR of each GA in the US market is, however, consistently higher than the RR of its corresponding IJVs in China. Overall, we conclude that the total number of involved vehicles per recall is similar, but that GAs are launching significantly more (voluntary) recalls per year in the US market. This conclusion agrees with the results obtained in Subsection 6.2.2.

**Table 10 Comparative analysis of sales and recall indicators for GAs in the US market and their corresponding Chinese IJVs (2009-2014)**

| Automakers | Name in US and China | SALE | NRE | NUR | NRPE | RR |
|---|---|---|---|---|---|---|
| GM | General Motor (US) | | | | | |
| | SAIC-GM (CHN) | ***0.0000***$^{C}$ | ***0.0000***$^{U}$ | ***0.0288***$^{U}$ | 0.0552 | ***0.0448***$^{U}$ |
| Nissan | Nissan (US) | | | | | |
| | Dongfeng Nissan (CHN) | ***0.0000***$^{U}$ | ***0.0072***$^{U}$ | 0.1288 | 0.6644 | ***0.0320***$^{U}$ |
| Hyundai-KIA | Hyundai-KIA (US) | | | | | |
| | DongfengYuedaKIA (CHN) | | | | | |
| | BeijingHyundai (CHN) | 0.4432 | ***0.0000***$^{U}$ | ***0.0224***$^{U}$ | 0.0536 | ***0.0212***$^{U}$ |
| Toyota | Toyota (US) | | | | | |
| | FAW Toyota (CHN) | | | | | |
| | GAC Toyota (CHN) | ***0.0000***$^{U}$ | ***0.0000***$^{U}$ | ***0.0000***$^{U}$ | 0.6100 | ***0.0361***$^{U}$ |
| BMW | BMW (US) | | | | | |
| | BBA (CHN) | ***0.0000***$^{U}$ | ***0.0000***$^{U}$ | ***0.0000***$^{U}$ | 0.4908 | ***0.0000***$^{U}$ |
| Ford | Ford (US) | | | | | |
| | Changan Ford (CHN) | ***0.0000***$^{U}$ | ***0.0000***$^{U}$ | ***0.0304***$^{U}$ | 0.0580 | ***0.0472***$^{U}$ |
| Honda | Honda (US) | | | | | |
| | Guangqi Honda (CHN) | | | | | |
| | Dongfeng Honda (CHN) | ***0.0000***$^{C}$ | ***0.0000***$^{U}$ | 0.0880 | 0.0688 | ***0.0044***$^{U}$ |
| Volkswagen | Volkswagen (US) | | | | | |
| | SAIC-VW (CHN) | | | | | |
| | FAW-VW (CHN) | ***0.0000***$^{C}$ | ***0.0384***$^{U}$ | 0.8720 | 0.8540 | ***0.0480***$^{U}$ |

[3] As the recall information on Hyundai and KIA in the NHTSA report is intertwined, we combine them into Hyundai-KIA for convenience; their data are merged as well.

## 7. Discussion and conclusions

Our findings are summarized in Table 11.

**Table 11 Summary of findings**

| Research level | Hypothesis | Reject? | | | |
|---|---|---|---|---|---|
| | | NRE | NUR | NRPE | RR |
| Country level | **H1**: There is no significant difference in the recall indicators between the US and Chinese Market, over the period 2004-2014. | Yes | Yes | Yes | Yes |
| Initiator level | **H2.1**: There is no significant difference between the mandatory recall indicators and the voluntary recall indicators within the US market. | Yes | No | Yes | NA |
| | **H2.2**: There is no significant difference between the voluntary recall indicators of the Chinese and US market. | Yes | Yes | No | Yes |
| Firm level | **H3.1**: There is no significant difference in recall performance between Chinese IJVs and CDAs. | Yes | Yes | No | Yes |
| | **H3.2**: There is no significant difference in the recall performance of IJVs depending on the nationality of the international partner (US, GER, KRA, JPN). | Yes | Yes | Yes | Yes |
| | **H3.3**: There is no significant difference in the recall performance of the GA in the US market, and the corresponding IJV(s) in the Chinese market. | Yes for all GAs | No for Nissan, Honda, VW Yes for other GAs | No for all GAs | Yes for all GAs |

"NA" refers to Not Applicable

Our findings support the argument that China lags far behind an established market such as the US in recall performance. Though this is relatively intuitive, the extent of the difference is unexpected. Apart from the difference in recall history length, this difference can be partly due to the rapid growth of the Chinese economy. Along with other industries, the auto industry has experienced exponential growth and, during the last decade, the car market in China is a strong seller's market. Due to the high-speed growth, automakers, part suppliers and dealers have focused more on the expansion of their capacities than on (developing management skills for) improving quality. At the same time, the Chinese government has not devoted adequate time and efforts to develop policies and standards to protect the consumers (Ban et al., 2006).

We have shown that, in the US market, the number of mandatory recall events is smaller than the number of voluntary recall events per annum; yet, they involve a larger number of units recalled. In other words, a mandatory recall campaign implies higher recall cost (on top of the heavy fines that come along with such mandatory recalls). This finding may explain why the number of voluntary recall events is significantly higher in the US than in China (where mandatory recalls are almost non-existent).

Our study suggests that ownership structure influences recall performance: IJVs outperform CDAs in terms of NRE, NUR, and RR (surprisingly, NRPE is shown to be independent of ownership structure). This suggests that IJVs pay closer attention to quality control than CDAs. This is likely due to the global partners of the IJVs, that insist on international quality standards (Ban et al., 2006), and thus create a learning opportunity for the Chinese partners (Nam, 2011). CDAs do not have this opportunity. The discrepancy between the recall performance of Chinese IJVs and CDAs may also reflect their strategic priorities, with the international parts of IJVs aiming to compete for market share globally while CDAs continue to prioritize sales in the domestic market. Though one might expect that the well-documented advantages of Japanese manufacturers (such as Toyota and Honda) in manufacturing efficiency, product design, and supply chain management (Cachon and Olivares, 2010; Olivares and Cachon, 2009) would lead to significantly better recall performance for their IJVs, we only observe clear superiority versus IJVs from other nationalities in the RR. When it comes to NRE, US-based IJVs are clearly superior versus all other nationalities. A rational explanation for this is that the US is the most developed country in vehicle recalls, as US automakers are particularly stimulated to launch voluntary recalls (e.g., through high fines imposed for mandatory recalls).

Finally, we observe that the recall performance of GAs in the US market is overall significantly better than the performance of their IJVs in the Chinese market (except for NRPE). This may be due to different factors. Despite the success of IJVs in China, conflicts between partners occur (e.g., in terms of culture, marketing strategies and quality management). For instance, the quality standard stipulated in the US may not be appreciated by the Chinese partner due to cost concerns (Ban et al., 2006). Also, research examining IJVs has indicated that IJVs mainly use a “passive” learning mode, in which production capabilities are strengthened but many other capabilities largely remain undeveloped (Nam, 2011). Differences in product safety rules in both countries are also a non-negligible factor.

While the general results of our work confirm that the Chinese market is still lagging the US market in terms of quality awareness and safety commitment, they also reveal that firms active in the Chinese market are working to close the gap: the time trends for the recall indicators in the Chinese market are clearly positive, while the trends in the US market are largely stable. The upward trend in the Chinese market is valid both for IJVs and CDAs, though IJVs tend to proceed at a faster pace than CDAs.

Our research has implications for regulators and managers. Strengthening automobile product recalls is crucial given the increasing attention to product safety issues in emerging markets. Based on our findings and previous insights from the literature (Haunschild and Rhee 2004), we argue that the Chinese government should take up a more proactive role in vehicle recall, for instance by approving and implementing stricter regulations on product quality, providing support for legal and scientific supervision by competent authorities, and empowering these authorities to issue mandatory recalls. In the US market, for instance, safety problems come to the NHTSA's attention either through vehicle owners reporting defects, or through the Environmental Protection Agency, or by conducting tests on vehicles purchased by NHTSA (Haunschild and Rhee, 2004; Rhee and Haunschild, 2006). In addition, the government should also enhance communication with automakers on product safety issues, and facilitate the general public's understanding of the responsible behavior of firms issuing recalls. Currently, CDAs mainly consider recalls as "a catastrophe", while GAs and IJVs are more likely to frame recalls as a part of routine business. A raise in awareness at CDAs is not only the key for their long-term viability, but also an absolute precondition if they want to sell vehicles to established markets. Instead of investing in capacity expansion, they should invest in increased quality awareness. Research shows that consumers react positively to recalls, when the recall is launched voluntarily and in a responsible manner (Hora et al., 2011). This result should encourage CDAs to act proactively in recalls.

Future research in this domain could include the following extensions: (i) Other emerging markets such as India, Brazil could be studied, in view of exploring similarities and dissimilarities with China (in terms of policies, as well as performance). (ii) Other industries such as the electronics, medical or toy industries could be assessed. (iii) Other performance metrics such as recall time (i.e., the time between the launch of the recall and the reparation of the associated defect), and significant factors affecting the metrics could be considered. Finally, empirical models could be used to further examine different causal factors affecting recall performance.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