40 Years of Economic Reform – The Case of Pudong New Area Open Economic Zone in Shanghai

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Abstract

This paper investigates the impact of special economic zones (SEZs) on economic growth. We use the Pudong New Area Open Economic Zone in Shanghai for our comparative case study and find this policy tool to have added up to CNY 7,166 to GDP per capita compared to a synthetic counterfactual without such a policy. Given that different reform policies were undertaken in different provinces including Shanghai itself even before the launch of the Pudong New Area Open Economic Zone, our findings might be considered conservative.

JEL Classification: C21, E02, O47, P21

Keywords: Augmented Synthetic Control Method, Bayesian Structural Time Series Model, Causal Inference, Comparative Case Study, Counterfactual, Economic Reform, Growth, Special Economic Zones

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1. Introduction

With the onset of economic reforms initiated by Deng Xiaoping in 1978, China has experienced an unprecedented success story with regards to economic growth (see Perkins, 1988, 1994, Cheung, 1986, 1998, and Storesletten and Zilibotti, 2014, for overviews of the reform process).[1] One of the cornerstones of the economic reforms is the so-called open-door policy (gaige kaifang). This policy of economic liberalization is mainly concerned with giving cities and provinces more autonomy with regards to economic development by granting them status of special economic zones (SEZs) (see Wei, 1995, Park and Prime, 1997, Yeung, Lee and Kee, 2009, Leong, 2013, and Alder, Shao and Zilibotti, 2016):

During the first wave of this new policy, four south-eastern coastal cities were granted SEZ status in August 1980.[2] Moreover, 72 cities were designated comprehensive reform experimenting cities in 1981. This was followed by a second wave in May 1984 during which 14 larger cities in the coastal provinces were declared open coastal cities which gave them the right to build Economic and Technological Development Zones (ETDZs) (Alder, Shao and Zilibotti, 2016, and Zheng et al., 2016).[3] Similarly, Hainan was given special status in 1983 which made it the single largest SEZ when becoming an independent province in 1988 (Wei, 1995, and Leong, 2013).

It is interesting to note that while cities and provinces along the Pacific coast spearheaded the reforms, Shanghai was not part of these pioneers, as the removal of benefits, entitlements and job security that went along with the reforms was feared to lead to resistance by the local government and the workforce (Horesh, 2013). Accordingly, economic development in Shanghai was not as fast-paced as in the rest of China: Province-level data from the China Statistical Yearbooks Database (CSYD) shows that while Shanghai had a higher GDP per capita than China as such, GDP per capita growth was much smaller. Starting with a per capita GDP of CNY 493 in 1981 for the entire nation, this number grew to CNY 1,900 by 1991, an impressive average annual growth rate of 14.56%. In comparison, per capita GDP in Shanghai stood at CNY 2,780 in 1981 and grew to CNY 6,670 by 1991, which translates into an average annual growth rate of 9.27% over this

[1] Readers interested in special topics of the reform process can find information on budgetary reforms, enterprise reforms and banking sector reforms in Sheng (1995), institutional reforms in Xu (2011) and rural reforms in Huang (2012).

[2] Shantou, Shenzhen and Zhuhai (Guangdong province) and Xiamen (Fujian province).

[3] Beihai, Dalian, Fuzhou, Guangzhou, Lianyungang, Nantong, Ningbo, Qingdao, Qinhuangdao, Tianjin, Weihai, Wenzhou, Yantai and Zhanjiang.

period (see Horesh, 2013, for similar numbers for the period 1978 to 1990). GDP per capita growth of Shanghai outpaced that of China for the first time since the start of the reform policies in 1992.

In this paper, we look at the contribution of the Pudong New Area Open Economic Zone which was estabslihed in the early 1990s to GDP per capita in Shanghai. Although Shanghai is one of the major cities in China with regards to both, economic activity and population, there is not much research on this topic. Wang (2013), and Alder, Shao and Zilibotti (2016) for example explicitly exclude Shanghai from their analysis for various reasons: On the one hand, Shanghai significantly differs from the rest of China with regards to main economic and socio-demographic indicators (see Table 1). On the other hand, while the early reforms focused on the manufacturing sector and international trade, i.e. setting incentives to attract foreign direct investment (FDI) and boost exports (see Park and Prime, 1997, Yao, 2006, and Zhao, 2013), the focus of the Pudong New Area Open Economic Zone is somewhat different, as it is more geared towards the Chinese capital market, as evidenced by the opening of the Shanghai Stock Exchange at the end of 1990. Accordingly, quantitative evidence on this matter is scarce.

Our aim is to fill this gap in the literature and assess the impact of the Pudong New Area Open Economic Zone on economic development of Shanghai which however is not trivial due to two reasons: First, given that many reform policies were put in place, a simple time series analysis of the development of GDP per capita in Shanghai will be biased by the economic upturn of China due to the reform policies launched in the late 1970s/early 1980s. Second, Shanghai differs significantly from the other Chinese provinces with regards to many control variables related to economic growth at the launch of the Pudong New Area Open Economic Zone; thus, a comparison of the development of GDP per capita of Shanghai with economic development in the rest of China would not only reflect the effect of the policy at hand but also the effect of differences in characteristics associated with economic growth in the pre-Pudong New Area Open Economic Zone period. Moreover, picking individual provinces as a yardstick seems questionable for several reasons: First and foremost, the choice of any province with which to compare Shanghai is subjective. Given that the Chinese provinces are heterogeneous, the results would depend on the particular choice of the control province. Second, an individual province might not be able to closely match the development of Shanghai before the launch of the Pudong New Area Open Economic Zone and thus be a bad counterfactual.

In general, such issues might be circumvented using the synthetic control method (SCM) first proposed by Abadie and Gardeazabal (2003). However, as Shanghai is the Chinese province with the highest per capita GDP as well as the highest values for some of the auxiliary covariates during the sampling period, it is not possible to perfectly reproduce Shanghai as a convex combination of the other Chinese provinces. Thus, we resort to the augmented synthetic control method (ASCM) recently suggested by Ben-Michael, Feller and Rothstein (2021) to construct the unobservable counterfactual, i.e. a synthetic Shanghai, as a combination of the other Chinese provinces so that it resembles Shanghai in the pre-Pudong New Are Open Economic Zone period. Augmenting the synthetic control method with a unit fixed effect model, we find that the opening up of Shanghai contributed up to CNY 7,166 in GDP per capita per year. Using ridge regression with fixed effects as the outcome model reduces the effect to CNY 5,597. The contribution of the Pudong New Area Open Economic Zone to economic development of Shanghai is most pronounced in 1999 after which the effect decreases and then stabilizes. However, even 12 years after the launch of the economic zone we do find an economically meaningful effect of more than CNY 4,000 additional GDP per capita using the fixed effects model (more than CNY 1,632 using ridge regression with fixed effects). To make sure that these results are not driven by our estimation strategy thus representing methodological artifacts rather than economic facts, we use the Bayesian structural time series (BSTS) approach developped by Brodersen et al. (2015) in a robustness check. When comparing the counterfactual constructed using the BSTS model with the actual Shanghai, we find that the opening up of Shanghai contributed an additional CNY 6,961 in GDP per capita per year on average, which corroborates the results from the augmented synthetic control method.

The remainder of this paper is structured as follows: Section 2 provides an overview of the literature related to the economic effects of the open door policy. Section 3 explains the methodology used to generate the counterfactual using the augmented synthetic control method as well as the Bayesian structural time series model. Section 4 describes the dataset. In Section 5, we present the empirical results, while Section 6 concludes.

– Please insert Table 1 about here –

2. Related Literature

One of the earliest empirical assessments of the effects of the open door policy can be found in Wei (1995), who uses two city-level datasets, the first containing 434 cities for the period 1988 to

1990 and the second 74 cities for the period 1980 to 1990.[4] The cities are categorized as either special economic zones (SEZs)[5], coastal open cities[6], or comprehensive reform experimenting cities[7], whereof only the coastal open cities dummy variable is statistically significant: With regards to economic growth, coastal open cities outpace other cities by 9.2% (17.8%) on average when employing the 1988 to 1990 dataset (1980 to 1990 dataset), respectively. However, when adding additional control variables, the effect becomes insignificant. In a similar vein, Leong (2013) employs two datasets to analyze the economic impact of the reform policies: The first dataset contains Chinese national data for the period 1970 to 2003, while the second dataset contains Chinese regional data covering 31 regions over the period 1978 to 2001. The impact of the reform policies dated in 1980 and 1991 is captured by two dummy variables. Using the national dataset, Leong (2013) finds that while the first wave of economic reforms in 1980 has no significant impact on GDP growth, the 1991-dummy is statistically significant. Likewise, the number of SEZs has a positive impact on economic development. Compared to Wei (1995), the reported effect is much smaller though, as an increase in the number of SEZs by 1% increases GDP by only 0.0045%. Moreover, when adding additional controls, only the 1991 reform-dummy remains statistically significant which suggests that speeding up liberalization seems to be more important than increasing the number of SEZs. When using the regional dataset and employing dummy variables to indicate SEZs and coastal open cities, Leong (2013) finds no significant effect of the coastal dummy and a statistically significant negative effect of the SEZ dummy.

One reason for the contradictory and counterintuitive findings reported by Wei (1995) and Leong (2013) across their datasets rests in the econometric approach, as pooled regressions might be suboptimal. Accordingly, Alder, Shao and Zilibotti (2016) study the impact of the establishment of SEZs on economic development using difference-in-difference estimation in a panel of 276 Chinese prefecture-level cities for the period 1988 to 2010. Their findings indicate that the establishment of SEZs increases a city's GDP level (GDP per capita) by about 12% (9%), respectively. The cumulative long-term effect yields an increase of the GDP level of about 20%.

[4] However, a look at the number of observations provided in the tables reveals that the effective datasets are much smaller, ranging from 120 to 347 observations for the 1988 to 1990 data, and 14 to 43 observations for the 1980 to 1990 data, respectively.
[5] Those 4 cities that were granted special economic zone status in August 1980.
[6] Those 14 cities along the Pacific coast that were granted open coastal city status in May 1984.
[7] Those 72 cities designated as comprehensive reform experimenting cities in 1981.

Rather than focusing on the mere presence or number of SEZs, Zheng et al. (2016) analyze the impact of the geographic stretch of development zones on economic growth. Using a sample of 95 development zones over the period 2003 to 2012 across China, they find that development zones have a positive contribution to economic growth in already developed regions. However, with regards to their size, development zones have a below proportional contribution to economic growth. The positive impact of development zones is confirmed on the provincial level by using the 74 economic development zones in Guangdong province over the period 2000 to 2008 as an example for a developed province.

A related strand of literature taking a somewhat different approach focuses on augmented production functions. Park and Prime (1997) employ an export-augmented production function to analyze province-level data for 26 provinces over the 1985-1993 period and find a strong positive effect of exports on economic performance which is driven by positive export-related externalities and a higher relative factor productivity of the export sector. Moreover, the effect is larger for coastal provinces which the authors attribute to the SEZs and open cities established along the Pacific coast but do not provide any econometric assessment of this proposition. Similarly, Yao (2006) augments a standard Cobb-Douglas production function (Cobb and Douglas, 1928) with additional variables related to the internal (human capital, infrastructure, location, institution, population pressure and saving behaviour) and external (FDI, exports and exchange policy) environment. The results using a panel of 28 provinces between 1978 and 2000 point to the impact of exports on GDP being much larger than the impact of FDI. However, while both exports and FDI are especially strong in the eastern provinces, there is no such effect on GDP itself. Given these findings, Yao (2006) suggests that adoption of leading technologies and business practices as well as promoting exports seem to be useful development policies for transitional countries. Similarly, Zhao (2013) employs a panel of 31 provinces from 1978-2008 and augments the production function with measures of FDI and the degree of privatization. Disentangling the effects shows that while both coefficients are statistically significant at the 1% level, FDI has a much larger contribution to GDP than privatization.

To the best of our knowledge, there exists no quantitative assessment of the impact of the Pudong New Area Open Economic Zone on economic development of Shanghai. Accordingly, we contribute to the literature by filling this gap.

3. Estimation Strategy

Table 1, columns (1) and (2), presents the mean values for GDP per capita as well as variables associated with economic growth (Abadie and Gardeazabal, 2003, and Barro and Sala-i-Martin, 2004) for Shanghai and China in the period 1981 to 1990, i.e. before the establishment of the Pudong New Area Open Economic Zone. In this period, Shanghai's GDP per capita was more than four times higher than that of the whole country (CNY 4,014 vs. CNY 978, respectively). Moreover, Shanghai was more densely populated as it had 17 times as many persons per square kilometer, had an unemployment rate that was half of that of China and a higher ratio of capital investment to GDP. Furthermore, the industrial structure of Shanghai significantly differed from the rest of the country, especially with regards to the contribution of the primary and secondary industry. Hence, a naïve comparison of Shanghai and the rest of China after the establishment of the Pudong New Area Open Economic Zone will not only reflect the impact of this economic policy tool but also other differences that affect economic growth.

To circumvent this issue, we compare the economic development of Shanghai with that of a weigthed combination of the other Chinese provinces where the weights are chosen in a way to resemble Shanghai before the launch of the Pudong New Area Open Economic Zone. That is, we compare the actual Shanghai against a synthetic counterfactual without an open economic zone. Recently, several different approaches for policy evaluation and construction of synthetic counterfactuals have been proposed, such as the augmented synthetic control method of Ben-Michael, Feller and Rothstein (2021) and the Bayesian structural time series modelling approach of Brodersen et al. (2015).

3.1. Augmented Synthetic Control Method

The synthetic control method (SCM) originally proposed by Abadie and Gardeazabal (2003) has been coined "the most important innovation in the policy evaluation literature in the last 15 years" (Athey and Imbens, 2017, p. 9), with applications ranging from the analysis of execution moratoriums and their effect on homicides (Ahrens, Kovandzic and Vieraitis, 2015), a paper considering the economic cost of mafia activity (Pinotti, 2015), an assessment of the impact of the European Economic and Monetary Union (EMU) on long-term government bond yields (Mäkelä, 2016), a study of how the L'Aquila earthquake affected university enrolment (Cerqua and Di Pietro, 2017), an examination of the economic cost of Brexit (Born et al., 2019), a quantification of the economic impact of the transfer of sovereignty over Hong Kong (Li, Sangal and Shao, 2021) to the evaluation of the labour force participation impact of pretrial justice reforms (Kim and Koh, 2021). Usage of SCM strongly relies on a proper pre-treatment fit of the counterfactual. Moreover, SCM constrains the weights attached to units in the donor pool to be nonnegative and sum to one in order to safeguard against extrapolation outside the support of the predictors (Abadie and Gardeazabal, 2003, and Abadie, Diamond and Hainueller, 2010, 2015). Given that Shanghai is the province with the highest values of some of the covariates during the sampling period (e.g. population density), it is not possible to perfectly reproduce Shanghai as a convex combination of the other Chinese provinces (see Figure A1 in the Online Appendix). To overcome the issue of infeasible pre-treatment fit, Ben-Michael, Feller and Rothstein (2021) suggest to augment SCM with an outcome model in order to estimate the bias due to the divergence between the treatment unit and the synthetic counterfactual and then adjust the original SCM estimate for this bias.[8]

Consider a panel dataset with $i = 1, \dots, N$ units observed over $t = 1, \dots, T$ periods. Let W_i indicate treatment of unit i in period $T_0 < T$. Furthermore, let $\hat{\gamma}_i^{scm}$ denote the SCM weights (see Abadie and Gardeazabal, 2003, and Abadie, Diamond and Hainmueller, 2010, 2011, 2015 for in-depth descriptions of the traditional synthetic control method) and $\hat{m}_{iT}$ be an estimator for the post-treatment control potential outcome $Y_{iT}(0)$. The ASCM estimator of the unobserved counterfactual $Y_{1T}(0)$ is then defined as

$$\hat{Y}_{1T}^{aug}(0) = \sum_{W_i=0} \hat{\gamma}_i^{scm} Y_{iT} + \left(\hat{m}_{1T} - \sum_{W_i=0} \hat{\gamma}_i^{scm} \hat{m}_{iT}\right) \quad (1)$$

$$= \hat{m}_{1T} + \sum_{W_i=0} \hat{\gamma}_i^{scm} (Y_{iT} - \hat{m}_{iT}), \quad (2)$$

Accordingly, ASCM explicitly takes the imbalance of the pre-treatment outcomes via $\hat{m}(\cdot)$ into account; $\hat{m}_{iT} = const.$ yields traditional SCM as a special case.

Among different outcome models, Ben-Michael, Feller and Rothstein (2021) propose to use ridge regression which allows negative weights. ASCM then penalizes the degree of extrapolation outside the convex hull (i.e. the deviation from the SCM weights) using a regularization parameter to balance the bias-variance trade-off. In this case, the estimator for the post-treatment outcome is

$$\hat{m}(\boldsymbol{X}_i) = \hat{\eta}_0^{ridge} + \boldsymbol{X}_i' \hat{\boldsymbol{\eta}}^{ridge}, \quad (3)$$

where $\hat{\eta}_0^{ridge}$ and $\hat{\boldsymbol{\eta}}^{ridge}$ denote the coefficients obtained from the ridge regression of control post-treatment outcomes $\boldsymbol{Y}_{0T}$ on centered pre-treatment outcomes $\boldsymbol{X}_0$:

[8] An alternative approach is to manually correct the pre-treatment gap by adding the average pre-treatment difference between the treated unit and the counterfactual to the mean of the outcome variable of the donor pool; see Li, Sangal and Shao (2021).

$$\{\hat{\eta}_0^{ridge}, \hat{\boldsymbol{\eta}}^{ridge}\} = \arg\min_{\eta_0, \boldsymbol{\eta}} \frac{1}{2} \sum_{W_{i=0}} \left(Y_i - (\eta_0 + X_i' \boldsymbol{\eta})\right)^2 + \lambda^{ridge} \|\boldsymbol{\eta}\|_2^2, \tag{4}$$

where λ^{ridge} denotes the penalty hyperparameter controlling the degree of extrapolation as well as the improvement in pre-treatment fit compared to traditional SCM. Hence, the ridge ASCM estimator is given as

$$\hat{Y}_{1T}^{aug}(0) \sum_{W_i=0} \hat{\gamma}_i^{scm} Y_{iT} + \left(\boldsymbol{X}_1 - \sum_{W_i=0} \hat{\gamma}_i^{scm} \boldsymbol{X}_i\right) \times \hat{\boldsymbol{\eta}}^{ridge}. \tag{5}$$

3.2. Bayesian Structural Time Series Model

In order to assess the robustness of our findings, we follow the recommendation of Athey and Imbens (2017) and use a different method to run a sensitivity analysis. The Baysian structural time series (BSTS) approach suggested by Brodersen et al. (2015) employs a diffusion-regression state-space model to construct the synthetic control and thus generalizes difference-in-difference estimation to time series modelling. As the name implies, the effect of the treatment (launch of the Pudong New Area Open Economic Zone) on the response variable (GDP per capita of Shanghai) is calculated using Bayesian estimation and model averaging to construct the counterfactual. Selection of control units for construction of the counterfactual is based on how well they explain the dependent variable of the treated unit before the intervention and does not rely on additional independent variables (i.e. growth predictors). The state-space representation of a structural time series model can be described by (see for example Scott and Varian, 2014, and Brodersen et al., 2015)

$$y_t = Z_t^T \alpha_t + \varepsilon_t, \tag{6a}$$

$$\alpha_{t+1} = T_t \alpha_t + R_t \eta_t, \tag{6b}$$

where Equation (6a) is the observation equation linking the observed data of the response variable y_t to the d-dimensional vector of unobserved latent states α_t and Equation (6b) is the transition equation governing the evolution of α_t throughout time. With regards to the pair of equations, Z_t denotes a d-dimensional output vector, T_t represents a $d \times d$ transition matrix, R_t is a $d \times q$ control matrix, and Q_t is a $q \times q$ state-diffusion matrix with $q \leq d$, while $\varepsilon_t \sim N(0, \sigma_t^2)$ and $\eta_t \sim N(0, Q_t)$ denote the observation error and the system error, respectively.

One of the advantages of the BSTS model is that it allows to use a spike-and-slab prior using forward-filtering, backward-sampling to efficiently reduce the set of potential control units to a parsimonious model (George and McCulloch, 1993, 1997, Scott and Varian, 2014, and Brodersen et al., 2015), thereby explicitly taking the posterior uncertainty concerning which regressors to include in the model as well as their strength on the predictions into consideration thus safeguarding against overfitting. More precisely, the spike-and slab prior consists of two parts, the spike which governs the probability of a regressor to be selected for the model (i.e. having a non-zero coefficient), and the slab that shrinks these non-zero coefficients:

Let $\varrho = (\varrho_1, \dots, \varrho_J)$ be a vector of ones and zeros where a value of one indicates a non-zero coefficient so that a regressor is selected, i.e. $\varrho_j = 1$ if $\beta_j \neq 0$ and $\varrho_j = 0$ otherwise. Accordingly, the spike-and-slab prior can be factorised as

$$p(\varrho, \beta, 1/\sigma_\varepsilon^2) = p(\varrho)p(\sigma_\varepsilon^2|\varrho)p(\beta_\varrho|\varrho, \sigma_\varepsilon^2). \tag{7}$$

While the spike part in Equation (7) might be any arbitrary distribution, the most common choice for the prior probability π_j of including regressor j in the model seems to be a product of independent Bernoulli distributions with the parameters set according to the expected model size M so that $\pi_j = M/J$. For the slab part, a conjugate normal-inverse Gamma distribution is used:

$$\beta_\varrho|\sigma_\varepsilon^2 \sim N\left(\boldsymbol{b}_\varrho, \sigma_\varepsilon^2\left(\Sigma_\varrho^{-1}\right)^{-1}\right), \tag{8a}$$

$$\frac{1}{\sigma_\varepsilon^2} \sim \Gamma\left(\frac{\nu_\varepsilon}{2}, \frac{s_\varepsilon}{2}\right), \tag{8b}$$

where $\boldsymbol{b}$ is a vector containing the prior expectation about the values of β, and ν_ε and s_ε can be interpreted as the prior number of observations and the prior sum of squares. To elicit the prior parameters in Equation (8b), an expected R^2 from the regression as well as the prior sample size ν_ε used to obtain this estimate are needed so that $s_\varepsilon = \nu_\varepsilon(1 - R^2)s_y^2$, where s_y^2 is the marginal standard deviation. The last parameter in Equation (8a), Σ_ϱ^{-1}, denotes the full-model prior information matrix, i.e. the elements of Σ^{-1} corresponding to non-zero β. For this matrix, Zellner's g-prior (Zellner, 1986, Chipman, George and McCulloch, 2001, and Liang et al., 2008), which sets $\Sigma^{-1} = \frac{g}{n}X^TX$, where X^TX is the total information in the covariates so that $\frac{1}{n}X^TX$ is the average information per observation and g denotes the number of observations worth of information, is used:

$$\Sigma^{-1} = \frac{g}{n}\{wX^TX + (1 - w)\text{diag}(X^TX)\}. \tag{9}$$

With regards to the posterior distribution, the Gibbs sampler (see for example Geman and Geman, 1984) is used for the Markov Chain Monte Carlo simulations of the model parameters and the counterfactual time series (see Scott and Varian, 2014, and Brodersen et al., 2015 for further details).

4. Data and Sample

Annual province-level data for the period 1981 to 2003 from the China Statistical Yearbooks Database (CSYD) is obtained via the China National Knowledge Infrastructure (CNKI) platform. The start date of our data is motivated by data availability as the database does not provide data necessary for our analysis for previous periods; in fact, publicly available statistical data for the period 1960 to 1980 is rare (Perkins, 1988). The sampling period ends in 2003 as about one and a half decades after the launch of the Pudong New Area Open Economic Zone provide a reasonable limit with regards to plausible prediction of the effect of this intervention. Moreover, the institutional context changed in 2004 due to the reorganization of development zones (Zheng et al., 2016), so that extending the data to the more recent past would confound our findings.

For both, ASCM and the BSTS model, we include all Chinese provinces other than Shanghai as potential donors for the counterfactual with the following exceptions: For Henan province, the CSYD reports CNY 10,604 million value-added of the primary industry in 1981 which results in a ratio of 4,247% to GDP. Accordingly, we set this value to missing in our analysis. For Jiangxi province, the database reports a population of 4.15 billion people in 2000 which results in a GDP per capita of CNY 48. As our analyses do not allow missing values in the response variable, we exclude Jiangxi from the sample so that 29 provinces are remaining to construct the counterfactual.[9]

While the BSTS model constructs the counterfactual without realying on additional independent variables, we include the following predictors of GDP per capita for the analyses using ASCM: Population density, the consumer price index, the urban registered unemployment rate, investment in capital construction, the industrial structure measured as the ratio of value-added to GDP of the primary, secondary and tertiary industry, and human capital measured as the ratio of graduates of primary schools and gradutes of regular secondary schools to size of population.

Dating the launch of the Pudong New Area Open Economic Zone is not trivial, as there seems to be no consensus in the literature: While Wei (1995), Leong (2013), and Hu, Fisher-Vanden and Su (2020) define the start date as 1990, Horesh (2013) mentions the 14$^{\text{th}}$ CCP Congress held in October 1992 as the official date that Pudong was decided to spearhead the economic development of the Lower Yangtze Delta. We follow the rationale of Alder, Shao and Zilibotti (2016) and set the first year of the reform in 1991, i.e. one year after first talks about the Pudong New Area Open

[9] Anhui, Beijing, Chongqing, Fujian, Gansu, Guangdong, Guangxi, Guizhou, Hainan, Hebei, Heilongjiang, Henan, Hubei, Hunan, Inner Mongolia, Jiangsu, Jilin, Liaoning, Ningxia, Qinghai, Shaanxi, Shandong, Shanxi, Sichuan, Tianjin, Tibet, Xinjiang, Yunnan and Zhejiang.

Economic Zone. This choice is motivated by the fact that even initial talks such as those held between 1990 and the 14th CCP Congress in 1992 might lead to economic agents adjusting their expectations and thus real economic impact even before the formal launch of the Pudong New Area Open Economic Zone.

5. Results

5.1. Augmented Synthetic Control Method

Figure 1 shows the development of the treatment effect, i.e. the gap between GDP per capita of Shanghai and its synthetic counterfactual, using jackknife standard errors (Quenouille, 1949, 1956, and Tukey, 1958) in Panel A and jackknife+ standard errors (Barber et al., 2021) in Panel B, respectively. Please note that the method used to calculate the standard errors does not affect the point estimates of the effect itself. Using a unit fixed effects model as the outcome model in ASCM yields an average treatment effect on the treated (ATT) of CNY 4,467, ranging from a low of CNY 326 in the first year after the launch of the Pudong New Area Open Economic Zone to a maximum of CNY 7,166 additional GDP per capita in 1999, after which the effect stabilizes and then tapers off. Based on the 95% confidence interval, the effect is statistically significant; as uncertainty increases further out into the future, the confidence band widens so that from 2000 onwards the effect is no longer significant, although the point estimate being some CNY 4,335. With regards to pre-treatment fit, this model specification achieves an improvement over uniform weights of the donor provinces of 79.7%. The overall bias of traditional SCM for which ASCM with fixed effects corrects is CNY 1,313.[10]

While achieving excellent pre-treatment fit, adding unit fixed effects to SCM is arguably on the simpler end of the range of possible outcome models. Thus, we follow Ben-Michael, Feller and Rothstein (2021) who make a strong case for ridge regression as the outcome model of choice. Further augmenting SCM with ridge regression reduces the ATT to CNY 3,212. Likewise, the point estimates for the post-treatment periods are lower, reaching a maximum of CNY 5,597 in 1999 and decreasing thereafter. Not surprisingly, pre-treatment fit increases so that usage of ridge regression with fixed effects yields an improvement over the mean of the other provinces of 85.5%, while the bias reduces to CNY 1,290.

[10] When using traditional SCM, the difference between Shanghai and its synthetic counterfactual in the pre-treatment period ranges between CNY 1,085 in 1984 and CNY 1,549 in 1990, being CNY 1,301 on average. See Figure A1 in the Online Appendix for the trajectories using traditional SCM.

– Please insert Figure 1 about here –

Next, we complement the evidence from the ASCM using a cross-sectional placebo study which is similar in nature to permutation tests (Abadie, Diamond and Hainmueller, 2010). More precisely, we rerun ASCM for all provinces in the donor pool in order to check whether our estimats could be driven by chance, i.e. how often would we observe an effect of this magnitude if we pick a province at random. If we find effects of a similar magnitude as we do for Shanghai, the estimated GDP per capita gap is not significant at all. However, if to the contrary we find that the GDP per capita gap for Shanghai is exceptionally large compared to that for the other provinces, the impact of the Pudong New Area Open Economic Zone on GDP per capita in Shanghai is statistically significant. As it is possible to calculate the exact distribution of the estimated effect of the placebo studies, this approach falls into the category of exact inference (Abadie, Diamond and Hainmueller, 2010).

Figure 2 presents the aggregate findings of these cross-sectional placebo tests: None of the placebo studies yields a GDP per capita gap of a similar magnitude we observe for Shanghai. The province with a GDP per capita gap closest to that reported for Shanghai is Jiangsu, which might be explained by the fact that Jiangsu had a similar industrial structure and the second highest GDP per capita during the observation period. For some provinces we even find a negative effect (e.g. Gansu, Guizhou, Liaoning or Shaanxi). Only towards the very end of the sampling period do we observe an effect of a similar size as the GDP per capita increase for Shanghai. Given that we run placebo studies for 29 provinces, the probability of estimating a gap of the same magnitude we observe for Shanghai under a random permutation of the intervention is 3.45%, below the 5% level typically used in tests of statistical significance (Abadie, Diamond and Hainmueller, 2010).

– Please insert Figure 2 about here –

5.2. Bayesian Structural Time Series Model

As we have no prior believes concerning the contribution of specific provinces to the counterfactual, we follow the literature and set $\boldsymbol{b} = 0$ in Equation (8a) of the spike-and-slab prior. Likewise, for the g-prior in Equation (9) we use the default settings, i.e. $g = 1$ and $w = 1/2$ (see Scott and Varian, 2014, Brodersen et al., 2015, and Pinilla et al., 2018). For the prior inclusion probability, we choose 0.10 for all potential predictors and draw 100,000 MCMC samples for the

Markov Chain Monte Carlo simulation. Given that observations in our dataset are sampled at annual frequency, seasonality should not be an issue (a time series plot of per capita GDP confirms this conjecture). Moreover, as the relationship of per capita GDP between the potential control provinces and Shanghai shows reasonable stability, we use static regression coefficients, i.e. $Z_t = \beta^T \boldsymbol{x}_t$ and $\alpha_t = 1$.

With the exception of Tibet (inclusion probability 0.08) all potential donor provinces exceed the prior inclusion probability of 0.10 and thus contribute to the counterfactual. Table 2 shows the estimates for the effect of the launch of the Pudong New Area Open Economic Zone on GDP per capita in Shanghai. The average GDP per capita in Shanghai during the post-Pudong period (i.e. 1991-2003) was CNY 23,537 which contrasts with CNY 16,576 for the counterfactual, i.e. the average GDP per capita that would have been observed without the intervention. Thus, this policy has contributed about CNY 6,961 to GDP per capita per year on average, with a 95% confidence interval of [CNY 1,108; CNY 12,910]. The cumulative impact over the entire 12 years during the post-Pudong period is CNY 83,538, with a 95% confidence interval of [CNY 13,297; CNY 154,918]. In relative terms, this translates into a 42% increase of GDP per capita in Shanghai after the launch of the Pudong New Are Open Economic Zone with a 95% confidence interval of [6.7%; 78%]. The positive effect observed during the post-Pudong period is statistically significant and unlikely to be due to random fluctuations; given the Bayesian one-sided posterior tail-area probability of $p < 0.011$, the probability of obtaining an effect of the given size by chance is very small. The posterior probability of a causal effect of the Pudong New Area Open Economic Zone on GDP per capita in Shanghai is 98.87%.

– Please insert Table 2 about here –

Figure 3 provides a graphic illustration of the results from the BSTS model. The development of GDP per capita for Shanghai (solid line) and the counterfactual (dashed line) as well as the 95% confidence interval of the prediction (shaded area) are presented in the upper Panel, the causal impact (calculated as the difference between GDP per capita in Shanghai versus the counterfactual) together with the 95% confidence interval is displayed in the middle Panel and the cumulative impact is shown in the bottom Panel. The counterfactual obtained from the BSTS model closely matches Shanghai in the pre-intervention period so that the difference between the two hovers around zero. After the launch of the Pudong New Area Open Economic Zone in 1991, GDP per capita in Shanghai starts to exceed that of its synthetic counterfactual. Given that the 95% confidence interval does not include zero, the effect is not only of a meaningful magnitude but statistically significant. Similar to our results using ASCM, the confidence interval widens towards the end of our sampling period so that the effect is no longer significant.

– Please insert Figure 3 about here –

6. Conclusion

The reform policies initiated by Deng Xiaoping and the open-door policy together with the establishment of special economic zones spurred unprecedented growth of the Chinese economy, lifting hundreds of millions of people out of poverty. While there is ample research on the economic effects of SEZs, to the best of our knowledge there is no analysis dealing with the Pudong New Area Open Economic Zone in Shanghai. Given that Shanghai is one of the most important Chinese cities in terms of economic activity, our research aims to fill this gap. We use the augmented synthetic control method of Ben-Michael, Feller and Rothstein (2021) and the Bayesian structural time series approach of Broderdsen et al. (2015) to construct a synthetic counterfactual, i.e. a Shanghai without such a policy, to analyse the effects of the reform.

The results suggest that the opening up of Pudong had a substantial impact on the development of GDP per capita in Shanghai: Depending on the specification of the outcome model, we find an effect between CNY 5,597 to CNY 7,166 in additional GDP per capita per year which translates into an average effect on the treated between CNY 3,212 and CNY 4,467 in case of the ASCM, where the peak is located some 8 years after the reform after which the effect levels off. This finding is corroborated by the results obtained using the BSTS model which shows an annual effect of CNY 6,961 over the 1991 to 2003 period. Given that the results using two different estimation strategies are close, we are confident that our findings are not methodological artefacts. Moreover, as the remaining Chinese provinces which form the synthetic counterfactual are influenced by economic reform policies themselves, the GDP per capita gaps reported in this paper might be regarded as conservative. Similarly, while there is not much evidence of substantial spillover effects during the observation period (see e.g. Brun, Combes and Renard, 2002), any spillovers from the Pudong New Area Economic Zone to the other provinces would have led to an increase of their economic activity and thus pessimistic inferences working against overestimating the GDP per capita gap (Meyer, 1995, and Brodersen et al., 2015).[11]

Even more than four decades after the first experiments with SEZs, the topic remains on top of the agenda of Chinese policymakers, as evidenced by the launch of the Shanghai Free Trade Zone on 29 September 2013 (Storesletten and Zilibotti, 2014). Thus, our paper is of interest to academics and policymakers alike. Given that methodological developments in the analysis of economic policy interventions such as Bayesian structural time series models (Brodersen et al., 2015) and the augmented synthetic control method (Ben-Michael, Feller and Rothstein (2021) offer new and flexible tools, we leave the analysis of further reform policies as avenues for future research.

[11] For opposing evidence with regards to positive and statistically significant spillover effects of SEZs on neighbouring provinces and cities see Alder, Shao and Zilibotti (2016).

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Figure 1: Development of Per Capita GDP for Shanghai vs. Counterfactual – Augmented Synthetic Control Method

This figure shows the development of the GDP per capita gap between Shanghai and the synthetic counterfactual using the augmented synthetic control method of Ben-Michael, Feller and Rothstein (2021). All models include auxiliary covariates (see Table 1). The shaded area shows the 95% confidence interval based on jackknife standard errors (jackknife+ standard errors) in Panel A (Panel B).

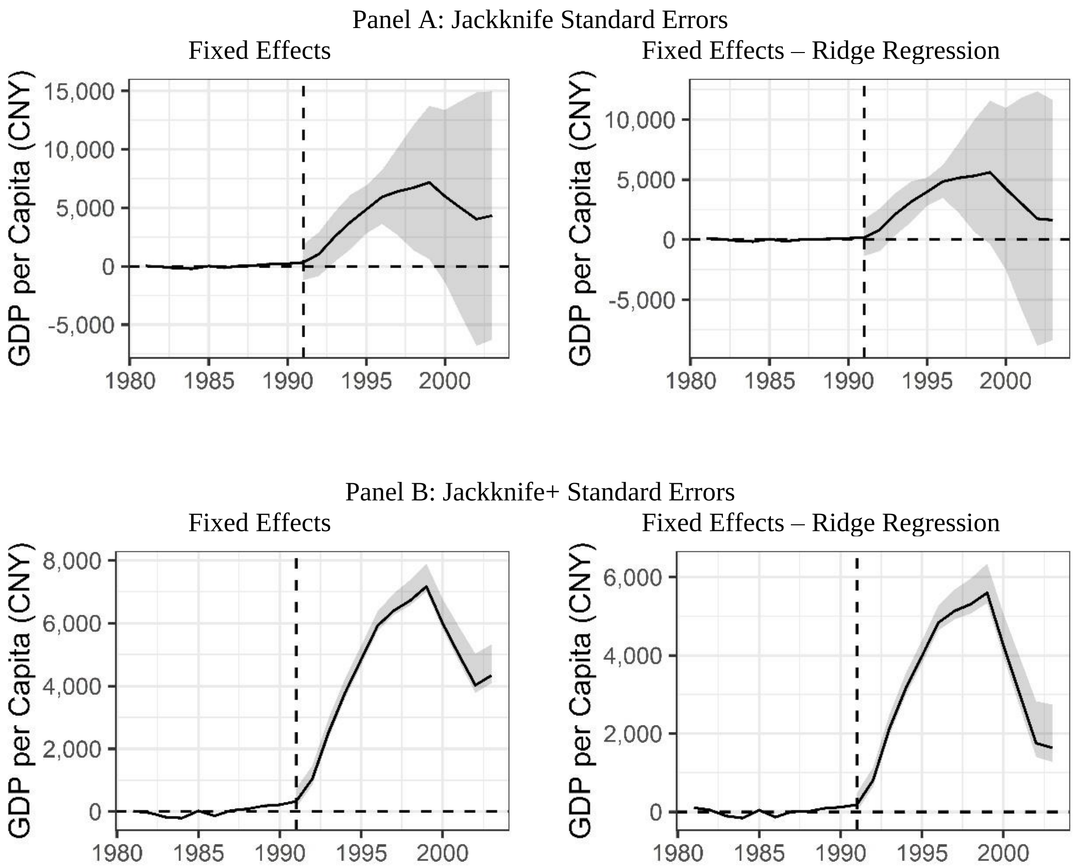

**Figure 2: Development of Per Capita GDP for Shanghai vs. Counterfactual –
Augmented Synthetic Control Method: Placebo Tests**

This figure shows the development of the GDP per capita gap between Shanghai and the synthetic counterfactual (solid line) as well as the respective GDP per capita gaps for 29 provinces (dashed lines) using the augmented synthetic control method of Ben-Michael, Feller and Rothstein (2021).

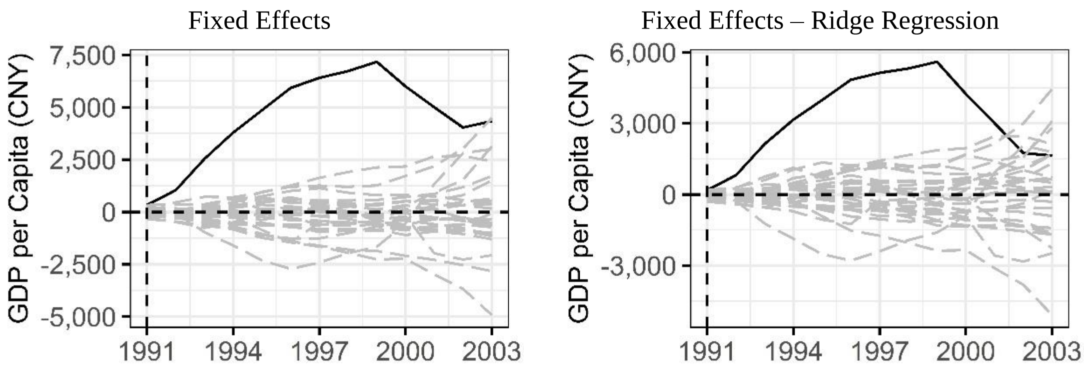

Figure 3: Development of Per Capita GDP for Shanghai vs. Counterfactual – Bayesian Structural Times Series Model

This figure shows the development of the GDP per capita gap between Shanghai and the synthetic counterfactual using the Bayesian structural time series model of Brodersen et al. (2015). The top Panel shows the trajectories of Shanghai (solid line) versus the synthetic counterfactual (dashed line). The middle Panel shows the estimated treatment effect, i.e. the difference between the trajectories of Shanghai and its synthetic counterfactual. The bottom Panel shows the cumulative treatment effect. The shaded area shows the 95% confidence interval.

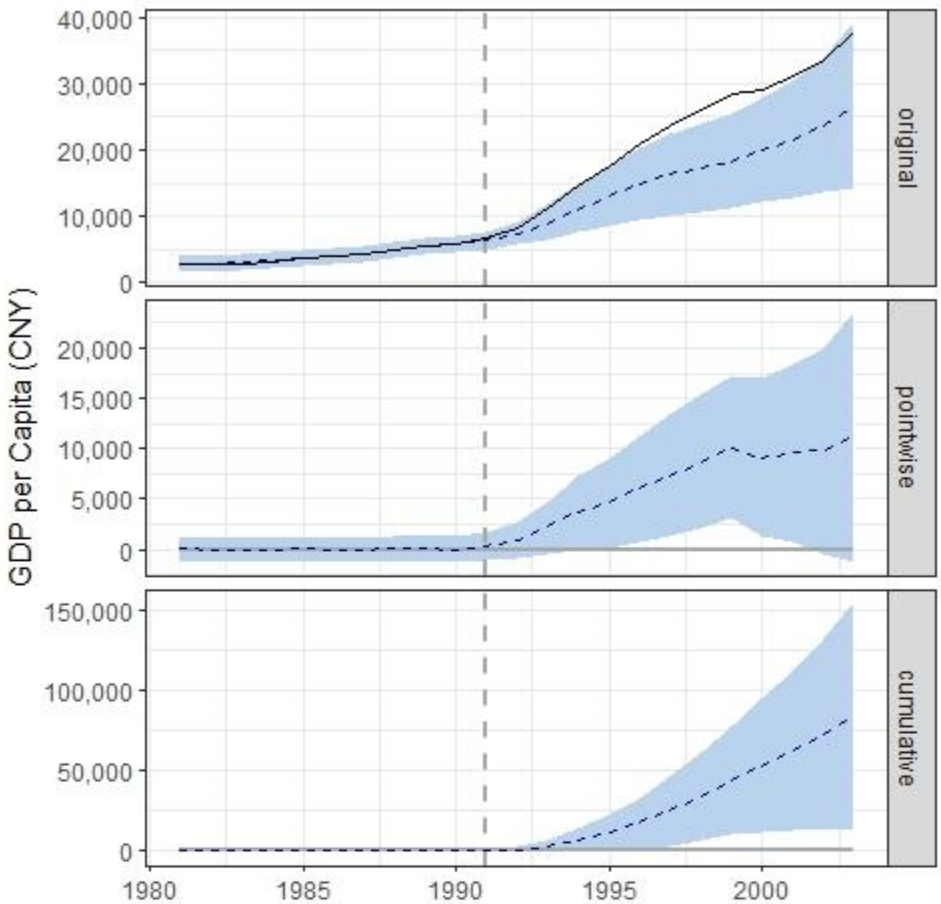

Table 1: Pre-Reform Policy Characteristics

This table presents the mean values for the dependent variable (GDP per capita) and the auxiliary covariates for Shanghai and China for the period 1981 to 1990, i.e., before the establishment of the Pudong New Area Open Economic Zone. [a] in Chinese Yuan; [b] persons/km²; [c] chain index (preceding year=100); [d] in %; [e] % of GDP; [f] % of population.

	Shanghai	China
GDP per Capita[a]	4,014.23	978.47
Population density[b]	1,978.50	111.40
Consumer price index[c]	107.60	107.22
Unemployment rate[d]	1.01	2.41
Investment in capital construction[e]	13.89	10.20
Value-added of primary industry[e]	4.05	28.55
Value-added of secondary industry[e]	69.57	43.44
Value-added of tertiary industry[e]	26.39	28.19
Graduates from primary schools[f]	1.01	1.86
Graduates from secondary schools[f]	1.19	1.24

Table 2: Posterior Inference of the Causal Impact of the Pudong New Area Open Economic Zone on GDP per Capita

This table presents the estimates of the causal impact of the launch of the Pudong New Area Open Economic Zone in 1991 on GDP per capita in Shanghai. Standard deviation in parenthesis. Values in squared brackets show the 95% confidence interval. Posterior tail-area probability $p = 0.011$ so that results are statistically significant at the 5% level. Actual, prediction and absolute effect in CNY; relative effect in %.

	Actual (1)	Prediction (2)	Absolute Effect (3) = (1) – (2)	Relative Effect (4) = (3) / (2)
Average Effect	23,537	16,576 (2,947)	6,961 (2,947)	42 (18)
		[10,628; 22,429]	[1,108; 12,910]	[6.7; 78]
Cumulative Effect	282,449	198,911 (35,362)	83,538 (35,362)	42 (18)
		[127,531; 269,152]	[13,297; 154,918]	[6.7; 78]

Online Appendix

Figure A1: Development of Per Capita GDP for Shanghai vs. Counterfactual

This figure shows the development of per capita GDP for Shanghai and the synthetic counterfactual using the synthetic control method of Abadie and Gardeazabal (2003). Panel A shows the trajectories for Shanghai (solid line) versus the synthetic counterfactual (dashed line). Panel B shows the per capita GDP gap between Shanghai and its counterfactual.