Shedding ”Light” on the Chinese Phillips Curve

A re-estimation with regional nightlight data

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Abstract

We use night light data as an proxy for output and wage data from micro sruvey to estimate a Phillips curve on a regional basis.

1 Introduction

2 Literature Review

Since the pioneering paper of Phillips [1958], the Phillips Curve has become an integral feature of Keynesian macro models. The early version of the Phillips Curve simply described the trade-off between inflation(wage) and output(unemployment). Friedman first emphasize the rule of expectation in the Phillips Curve. He claims that output would only react to unanticipated monetary fluctuation. Based on adaptive expectation, Solow and Gordon et al. argues that the policy can utilize the unemployment-inflation trade-off even in the long run, which is dismissed during the ”stagflation”. Then came the ”Lucas critique”(Lucas Jr) that individuals form expectations rationally based on current information and any attempt to calibrate a Phillips Curve from past is in vain.

Later on, New-Keynesian Phillips Curve (NKPC) based on full information rational expectation (FIRE) and sticky price (or wage) gradually prevailed. Settings such as a

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fixed contract duration(Taylor [1980]), information stickiness(Mankiw and Reis) and labor market search friction(Gertler and Trigari) can all generate such nominal rigidity. But most of the models are based on stagger pricing. In Calvo [1983], only a partion of the firms can reset their price based on the expectation of future markups in each period. The resulting Phillips Curve is $\pi_t = \beta E_t \pi_{t+1} + \kappa \tilde{y}_t$[1].Galı and Gertler accommodates firms' backward pricing and generates the Curve as $\pi_t = \lambda_f E_t \pi_{t+1} + \lambda_b \pi_{t-1} + \kappa \tilde{y}_t$[2]. In the real economy, the excess price markup $\tilde{MC}$ can also be influenced by supply shock such as commodity price fluctuation (Gordon [1997]). Thus the complete version of our model becomes $\pi_t = \lambda_f E_t \pi_{t+1} + \lambda_b \pi_{t-1} + \kappa \tilde{y}_t + \gamma ss_t$.

There is a vast empirical literature offering supportive evidence to the existence of the Phillips Curve in America. The first concern is to generate the output gap. Among many approaches[3], the HP filter suggested by Hodrick and Prescott, though not free from criticism, is widely used because of its tractability. Another major challenge is to estimate the expectation term. A branch of papers tried to incorporate survey data into the models(Coibion et al.). However, this approach is controversial (Lovell argues that assumptions are untestable) and the expectation proxied seems far from rational (Mankiw and Reis). Another branch of literature applies various econometric methods to estimate the Curve. For example, Schorfheide [2008] uses least square estimate and get a set of $\hat{\kappa}$'s and $\hat{\lambda}$'s in different decades using various filters. [4]. The resulting κ range from 0 to 0.03 and λ ranges from 0 to 0.005, which is far below what the theory implies. Importantly, he shows that LS regression underestimates these parameters in that the markup shock $\tilde{\xi}_t$ is negatively correlated with output (attenuation bias). He also claims that lagged output and inflation are weak instruments because the lagged endogenous variable is uncorrelated with current output in equilibrium.[5] Using DSGE model, he redresses his estimate for κ of 0.1 and λ in [0.1,0.2]. The author also lists a range of DSGE based estimates in other literature. Those estimates vary from 0.001 (Cho and Moreno [2006]) to 4.15 (Canova [2009]). The divergent results suggest the dynamic

[1]Here $\tilde{y} \sim \tilde{MC}$, some papers describe NKPC as $\pi_t = \beta E_t \pi_{t+1} - \lambda \tilde{MC}_t$.

[2]This equation is also called the "hybrid NKPC". It becomes purely forward-looking if we drop π_{t-1} from the R.H.S, and purely backward if dropping $E_t \pi_{t+1}$

[3]Like band-pass(BK) filter(Baxter and King [1999]), CF filter(Christiano and Fitzgerald [2003]), and production function method.

[4]The models here are essentially $\pi_t = \beta E_t \pi_{t+1} + \kappa \tilde{y}_t + \tilde{\xi}_t$ or $\pi_t = \beta E_t \pi_{t+1} - \lambda \hat{MC}_t + \tilde{\xi}_t$

[5]The uninformative property is model-specific. It was nevertheless still widely used, and also in Chinese academia.

nature of the Phillips Curve. But chances are that the approach is not robust enough to rule out any improvement in methodology.

The method adopted in our paper is simple in principle. The idea is to absorb part of the inflation expectation in the year fixed effect using panel data. Some literature has shed light on this approach. Ashenfelter et al. [1984] suggests that we can dispense with the effort to identify the supply shock and inflation expectation which is shared across regions. Using panel data from Canada, USA, and UK, he found that the Phillips Curve didn't disappear during the stagflation. DiNardo and Moore [1999] follows Ashenfelter's work and construct an open-economy Phillips Curve using panel data from 9 OECD countries. He estimates a coefficient of unemployment ranging from 0.3 to 0.6, which implies a κ of about 0.2. Both papers' estimates are larger than those mentioned earlier, suggesting that either the Phillips Curve in a larger scope is steeper, or the attenuation bias is not as a big deal as computed in Schorfheide [2008][6]. Based on their work, it's a natural idea to extend this research to China.

There are many papers concerning Chinese Phillips Curves. The early list of works discussed the external validity of the Phillips Curve in China and brought about some variations from the mainstream model. For example, Li argues that since the rural and urban labor market are separated in China, an increase of labor demand from the urban industry will attract more peasant workers instead of lowering the urban unemployment rate, indicating a vertical Phillips Curve. Zhang provides empirical evidence to this feature. But the validity of his result is compromised by the variation-lacking, suspect official unemployment data.

Most of the later works thus avoid using unemployment and focus on the output-gap based Phillips Curve. The first branch of them uses GMM. Chen found that κ lacks statistical significance but the coefficient of the lagged output gap is about 0.08(and significant), which is interpreted as the hysteresis of demand-side force. Zeng et al. [2006] also estimate some κ's from 0.26 to 0.52. Both papers choose lagged variables as instruments when conducting GMM, which would be improper according to Schorfheide. The second branch of papers simply adopts linear regression. Scheibe and Vines [2005] estimates a set of κ of a hybrid forward-looking NKPC in the magnitude of about 0.03. The third branch of works is based on structured models like DSGE and VAR. For

[6]scale down κ by 0.2 in LS regressions.

example, Zheng and Guo [2013] builds a small open economy model and estimates a κ of 0.86. Most of the estimates are higher than those of American Phillips Curves.

A few papers estimate the Chinese Phillips Curve from the panel data. Mehrotra et al. [2010] uses the annual data and estimates a κ of 0.006 for the hybrid NKPC without supply shock. The author also found the Phillips Curve is dynamic cross periods and varying cross provinces. Bin [2011] re-estimated the model and incorporated the supply shock proxied by the production of trade-dependency and the CRB index[7]. The estimate of κ is 0.013 based on quarterly data. Both papers incorporate π_{t+1} as the expectation term, whose significance implies that the inflation expectation also contains some local information. Both papers rely on the GMM method instrumented by lagged endogenous variables. Therefore, they didn't utilize the year fixed effect to absorb inflation expectation and supply shocks[8]. This paper will thus adopt the panel regression to update the estimate and to see if there are any structural changes in the recent two decades, given the dynamic property of the Phillips Curve. No work has been done at the city level. Thus we'll examine the existence of the Phillips Curve in a more local scope.

However, researches using official data are prone to the doubt of authenticity. For example, Movshuk [2002] emphasizes the possibility that local governments are driven to exaggerate the figure by performance pressure. Recently, night-light has become a popular proxy for local development (Michalopoulos and Papaioannou). And as an application in China, Kangning et al. uses this data to defend the authenticity of the Chinese official data by fitting the latter with the former. This paper will extend the estimate to a "night-light Phillips Curve" as an innovation and a robustness check.

3 Data Description

We derive the real output per capita y and GDP deflator π based on national nominal and real GDP and population derived from CEIC China Database. GDP per capita is more in line with the none population growth setting of the model than its gross counterpart. That's nevertheless slightly problematic in that a baby boom doesn't increase labor supply and won't affect natural output, but will lower the nature output per capita. Thus we

[7]CRB is a price index of 22 economy-sensitive commodities composed by the Commodity Research Bureau.

[8]Though Mehrotra et al. mentioned this advantage in his literature review

will observe an output gap even though all economic conditions are identical with that in line with the nature output. However, we assume it as a reasonable proxy since the population growth is much more stable than the output level.

4 Curve Estimates

In this sector, we first explain our theoretical model and its implications. Then we discuss the empirical results and compare it with the model's prediction.

We omit the deduction of the baseline Phillips curve1 that can be found in many textbooks (like Galí [2015]). Our focus is the slope of Phillips curve: $\kappa = (\sigma + \frac{\phi+\alpha}{1-\alpha})\lambda$, where $\lambda = \frac{(1-\beta\theta)(1-\theta)}{\theta}\frac{1-\alpha}{1-\alpha+\alpha\epsilon}$. Here $\hat{\mu}_t$ is the firms' extra price markup. $\frac{1}{\phi}$ is Frisch elasticity of labor supply. α is the capital share. σ is the parameter of CRRA utility. θ is the fraction of firms that can't reset their prices within a quater. ϵ is the goods' demand elsticity. β is the subjective discount rate. As in Galí's book,Under the baseline calibration of American economy that $\phi = 5, \beta = 0.99, \sigma = 1, \epsilon = 9, \alpha = 0.25, \theta = 3/4$, the slope terms are $\kappa = 0.17, \lambda = 0.02$, which are 0.68 and 0.08 annually.[9] However, the Phillips curves are steeper in those countries with a greater capital share. For example, assuming Chinese labor share is 0.7, the slope will increase to 1.32[10]. That indicates that the change in labor share is not neglectable for those countries away from the balanced path, facing structual changes like China. In that case, using $y_\alpha = \frac{1-\alpha}{2+16\alpha}\tilde{y}$ as the independent variable[11] would make more sense.

$$\pi_t = \beta E_t \pi_{t+1} - \lambda \hat{\mu}_t = \beta E_t \pi_{t+1} + \kappa \tilde{y}_t \tag{1}$$

This simplified model will also suffer from the unobservability of technology shocks which have impact on the natural level of output. The identification problem will be exacerbated in that the HP filter simply derive the cyclical part of output but can't tell whether it's caused by technological shocks or others like monetary or demand shocks, which doesn't impact the nature output. In order to address the issue, we provide additional support to our panel regression by adopting a DSGE model and try to identify

[9] Annual inflation is 4 times of quarter inflation but log output gaps are the same whether it's computed annually or quarterly.
[10] Under the baseline calibration, $\kappa = \frac{1-\alpha}{2+16\alpha}$.
[11] Though using the term "independent variable", we're not attempting to pin down the causality.

the technology shocks.

4.1 National Level NKPC

We first use HP filter 2 to compute the output gap from real GDP time series. As suggested by Ravn and Uhlig, we take $\lambda = 6.5$ for annual data. We follow the method in most literature using GDP deflator as the index of inflation but also adopt CPI as an auxilliary price index.

$$\min_{\tau_t} \left[\sum_{t=1}^{T} (y_t - \tau_t)^2 + \lambda \sum_{t=2}^{T-1} \{(\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1})\}^2 \right] \tag{2}$$

The Baseline OLS estimate, as shown in column (1), is higher than most empirical results (but lies in the range [0,4]). Under the assumption that inflation is relatively persistent, the slope could be biased up by the expectation term. If we assume people somewhat have backward formed expectation, we can partly address this problem by adding lagged term of inflation as shown in column (2) and (4). We also try to strictly align our estimate with the structure model and choose $\pi_t - \beta E_t \pi_{t+1}$ as the dependent variable. We proxy the expectation term using the lagged terms in column (3) and the surveyed inflation expectation in column (4). Nevertheless, these estimates either want statistical support or still lies above what implied by theory or reported in literatures.

Table 1: National Level Baseline Regression

	(1)	(2)	(3)	(4)	(5)	(6)
y_hp	1.362^{*}	0.795^{+}	0.566	3.996	3.273^{**}	1.516
	(2.46)	(1.73)	(1.42)	(0.22)	(3.09)	(1.74)
_cons	0.0552^{***}	0.0331^{***}	0.00285	2.682^{***}	0.105^{**}	0.960^{***}
	(7.23)	(3.99)	(0.41)	(9.13)	(3.08)	(132.61)
Inflation	Deflator	Deflator	Deflator	CPI	CPI	CPI
Subtract_Epi	No	No	Lag	No	No	Forward
Lags	No	L1 2 4	No	No	L1 2 4	No
N	40	36	39	41	37	15
r2_a	0.158	0.461	0.021	-0.024	0.996	0.086

t statistics in parentheses
$^{+}$ $p < .1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Though the baseline regression (1) has a relatively convincing statistical result, it's prone to criticism for not including the inflation expectation of any form. However, the column (2) (4) shows that neither the lagged term of inflation nor the surveyed

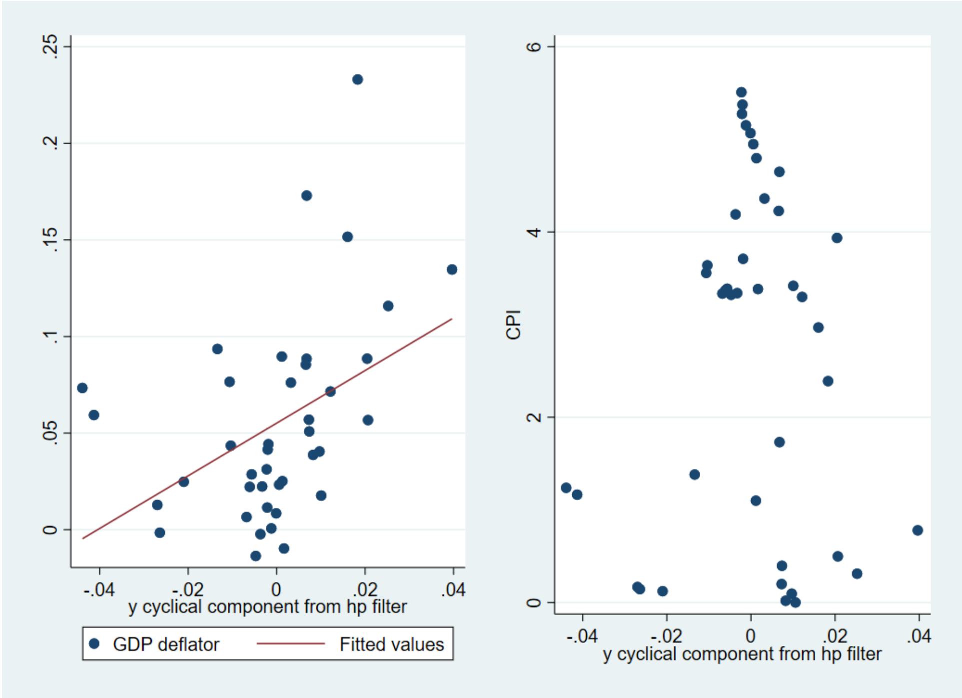

Figure 1: All observations: seemingly ramdom

expectation can catch enough variation in inflation expectation. Therefore, the Phillips curve doesn't seems to stand on a solid base at the national level unless we identify the expectation term or reestimate with a more complicated model.

4.2 Provincial Level NKPC

Unfortunately, the provincial level GDP deflator is not available. We instead deflate local GDP by national level GDP deflator, which can be verified more if the provinces have similar composition of their production. We will also use cpi to deflate nominal GDP and show that the result remains robust.

It's notoriously difficult to address the expectation term in Phillips curve whether by finding a proxy or use structured model. In this paper, one goal is to solve the dilemma using regional level data. There are two reasons for taking this approach. First, China didn't adopt its present economic institution until 1980s, which caused the scarcity of relevant national-level data compared to America. By using the province level data, we can greatly amplify our data and make the regression more robust. Second, the manipulation of interest rate and the vagueness of monetary policy rule make it hard to base the estimate on a structured model. Thus it's more convenient to contrive a method to identify the expectation term in the regression model. Now that all Chinese provinces are under a unified monetary and financial system while receiving shared information concerning macro policy or the fundamentals of economy that reasonably have impact on local economy, they will to some extent form their expectation about the local inflation based on the shared infomation . We assume that people's expectation is a combination of the past experience and the belief about the future. Then we can solve the expectation issue by using the lagged terms to proxy the backward looking part of the expectation and simply dispense with the effort on the forward looking part by letting the year fixed effect absorb it. Therefore, our baseline model3 is a regression equation containing both individual and year fixed effect.

$$\pi_{i,t} = \sum \alpha_i x_i + \sum \beta_t year_t + \kappa \tilde{y}_{i,t} + \epsilon_{i,t} \tag{3}$$

The graph below presents all the observations from 1980-2018. Each point represent a province in a year wich coordinate $(\tilde{y}_{i,t}, \pi_{i,t})$. Those observations as a whole seems totally random and we cann't see a positive relationship between inflation and output gap. Moreover, in 1990s there seems to be a significant negative relationship between the two variables. However, the graph is muted about the year and individual's fixed effect. Chances are that the seemigly random pattern is the result of a positive-slope Phillips curve moving from bottem-right to upper-left cross years.

In order to look deeper into this question, we first estimate the model without year or both individual and year fixed effects in column(1) and (2). Surprisingly, the estimated coefficient is significantly negative, probably due to the shift of Phillips curve cross time. In fact, that is the case of nearly all the provinces themselves alone. As shown in fig. 4, the negative relationship between local inflation and output gap is extremely prevailing. It's important to note that this result doesn't contradict the positive relationship between inflation and output gap observed at a national level. For example, one can conceive a country consist of two identical provinces in two years. The national observations in the output-gap-inflation system are the mid-points of the two provincial observations in the corresponding year, whose connection can be in any direction.

By similar reason, we can still expect a positive $\hat{\kappa}$ in out baseline model estimate in column(3) which would be in line with our model. The estimated slope 0.0952, which is close to the case where 60% of the firm can't ajust their price in one quarter and the labor income share is 50%. We also use y_α as our independent variable in column(4).

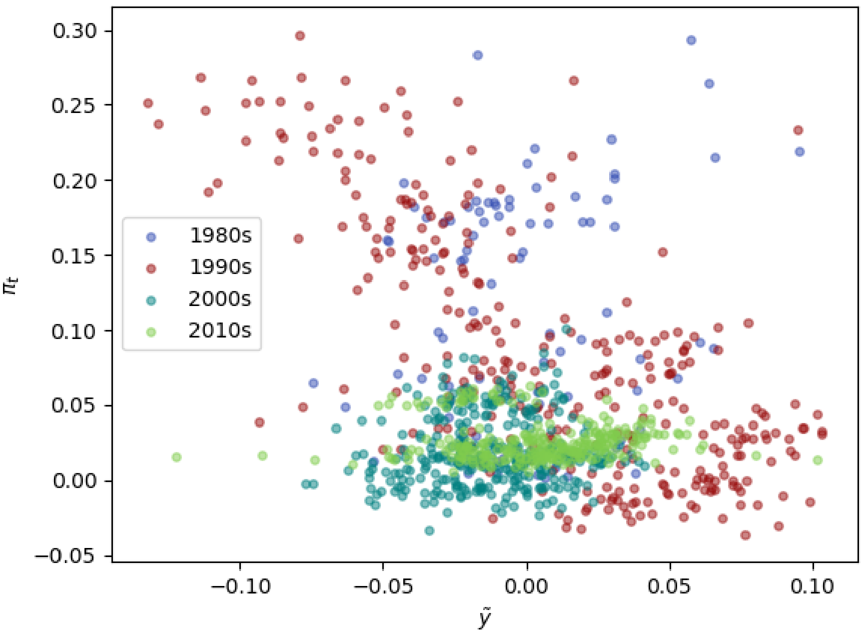

Figure 2: All observations: seemingly ramdom

Out estimate is higher than the coefficient implied by the theoretical model and baseline calibration, i.e. 1, but lies in a reasonable range. Finally, we try to pin down the backward expectation component by adding lagged 1,2 and 4 period terms of inflation into the regression. The results are shown in column (5) and (6), which is generally similar to baseline model.

We further investigate whether their is a "regional" version of Phillips curve for every single year. As shown in fig. 3, all the observations within one year lie close to a upward line. We tint each province with different color in order to justify that this result is not a simple fact of local variation. As we can see, and as guaranteed by HP filter, each province appear at different places of the line in different year. It's still ture if we subtract the backward expectation component from the inflation rate π_t.

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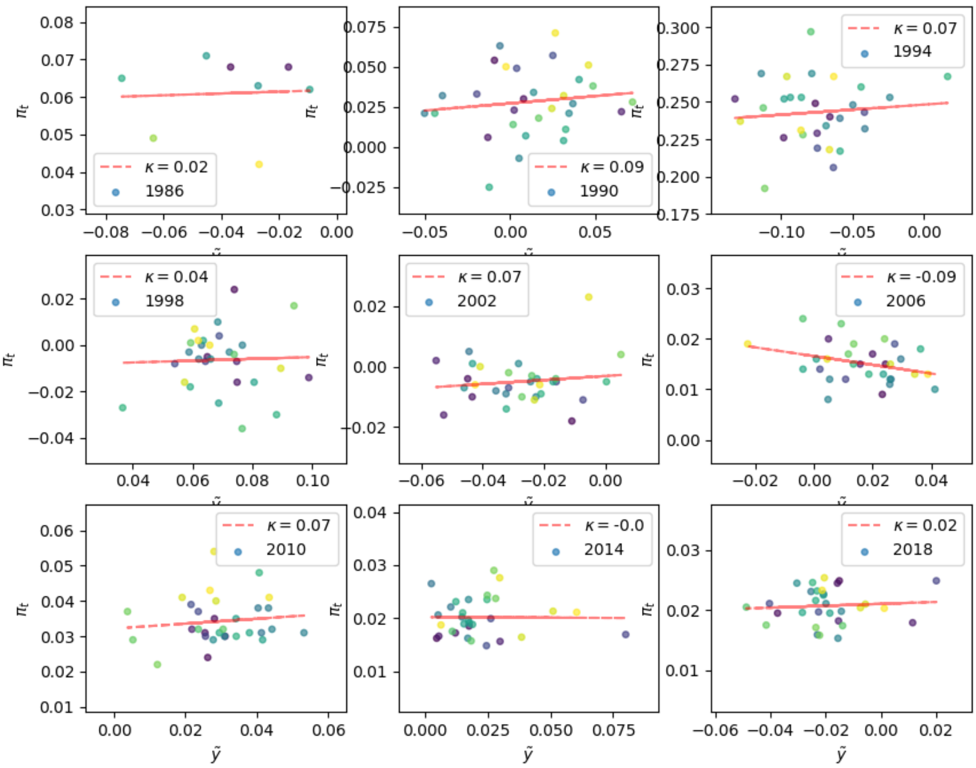

Figure 3: Observations in each year: Phillips Curves appear

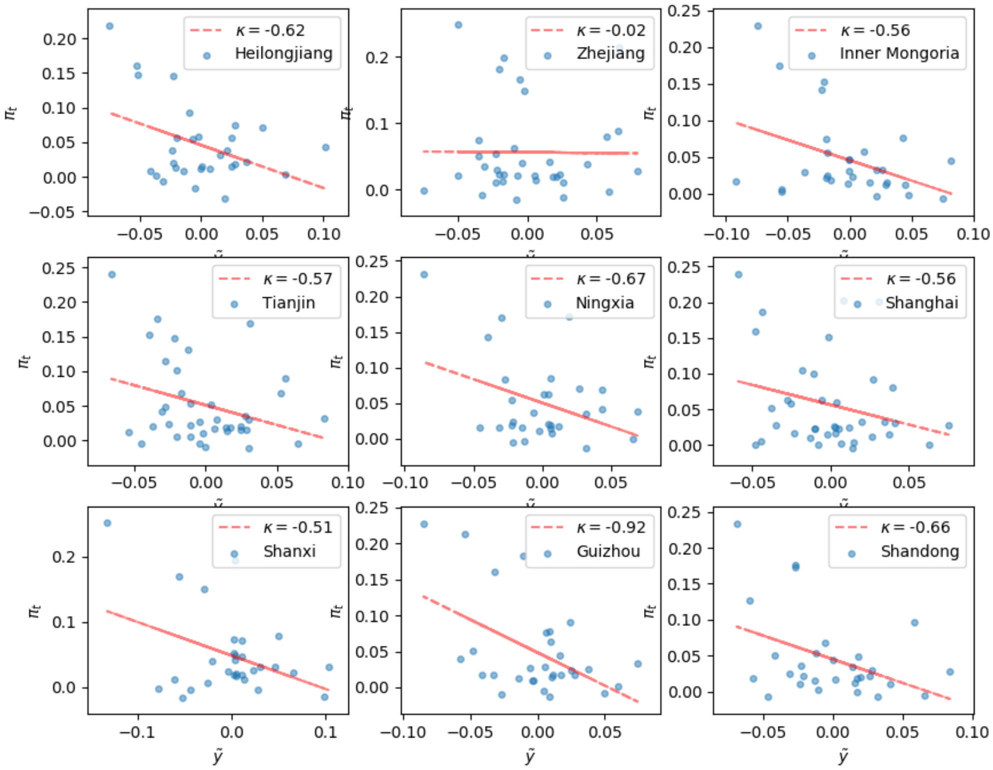

Figure 4: Observations in each province: ”negative slope puzzle”

Table 2: Provincial-level Baseline Regression

	(1) OLS	(2) FE	(3) FE	(4) FE	(5) FE	(6) FE
ln_y_real_hp	-0.549***	-0.550***	0.0952*			0.0895*
	(-7.74)	(-9.24)	(2.16)			(2.15)
lny_alpha				1.928*	1.404+	
				(2.13)	(1.82)	
L.p					0.234**	0.235**
					(2.84)	(2.91)
L2.p					-0.112	-0.105
					(-1.37)	(-1.36)
L4.p					-0.0211	-0.0159
					(-0.39)	(-0.31)
_cons	0.0494***	0.0494***	0.0587***	0.0557***	0.0212***	0.0233***
	(25.81)	(1697.82)	(14.96)	(34.78)	(6.02)	(5.48)
Year FE	No	No	Yes	Yes	Yes	Yes
ID_FE	No	Yes	Yes	Yes	Yes	Yes
Cluster	No	Yes	Yes	Yes	Yes	Yes
Lags	No	No	No	No	L1 2 4	L1 2 4
N	980	980	980	845	810	855
r2_a	0.101	0.102	0.952	0.954	0.958	0.959

t statistics in parentheses
$^{+}$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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A Summary Statistics

Table 3: Summary Statistics

	(1)	
	Provincial	
	mean	sd
ln real GDP per capita	8.61	1.64
GDP deflator (last year=1)	1.06	0.05
CPI	0.05	0.06
Observations	1209	