INDUCED INNOVATION AND LABOR PRODUCTIVITY IN CHINA

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Factor-Price-Induced Innovation and Labor-Productivity Growth

- Innovation impacts labor productivity (Output per Unit of Labor: Y:L)
- Has increasing labor cost induced innovation in China? Directly or indirectly through adapting labor-saving technology already available at the world technology frontier
- Is there evidence of geographical dispersion in the rate of innovation in China?
- How well does labor productivity growth track other measures of innovation?
  - Patent activity
  - R&D activity
  - Growth of physical capital
- What are the implications of labor-saving innovation for
  - The distribution of income (factor shares)?
  - The distribution of income (wage inequality)?

Real Wage Growth in China

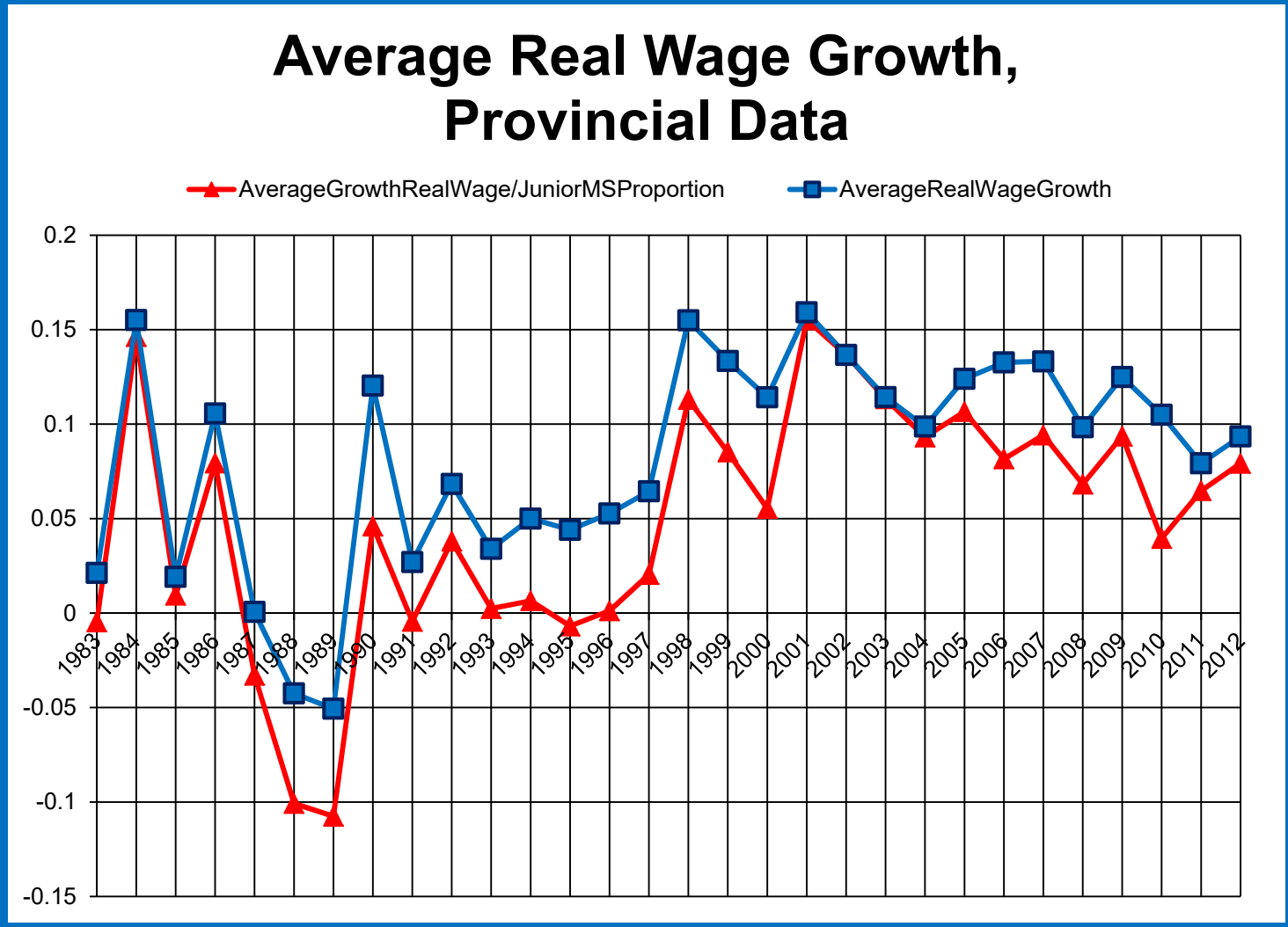
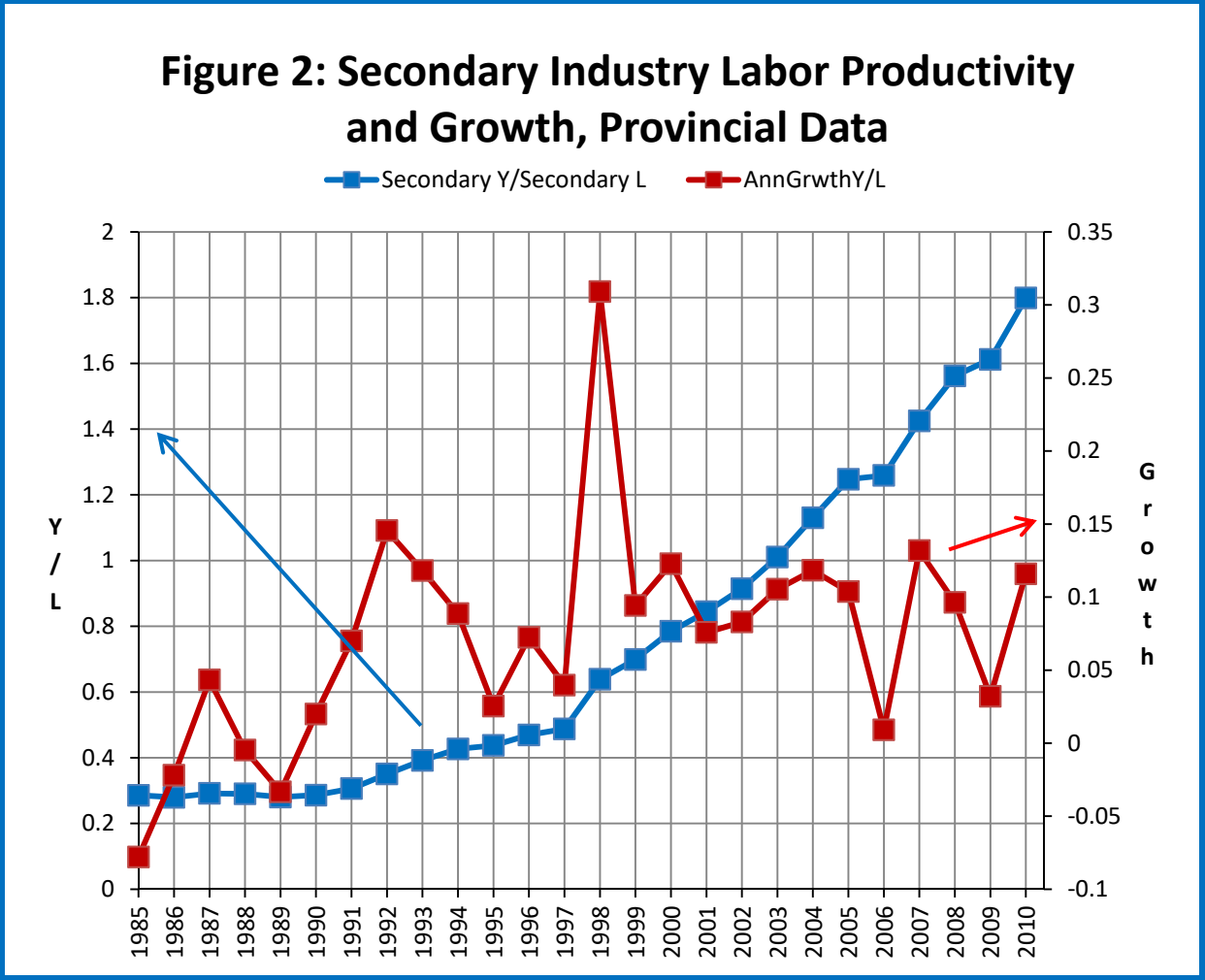
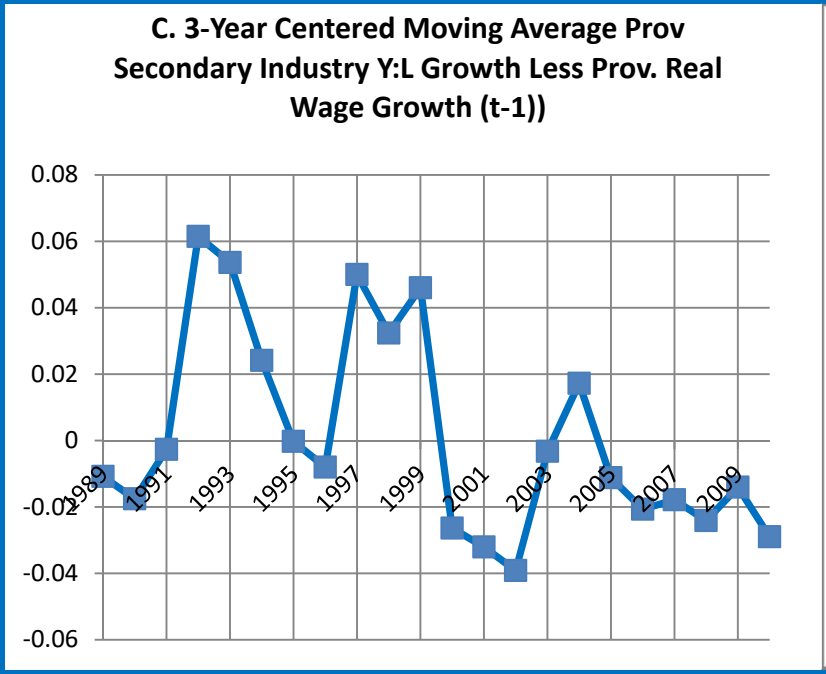
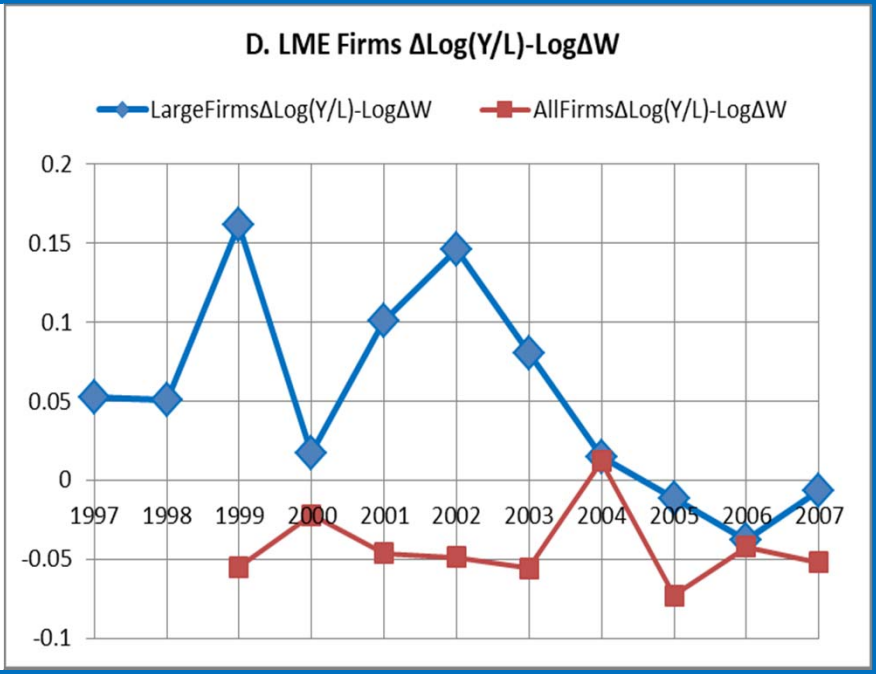


Figure 2 shows that labor productivity (Y/L) rose continuously throughout the period 1985-2011.



However, Y/L growth exceeded real wage growth consistently in the decade preceding China's entry into WTO, but less so in the several years following.



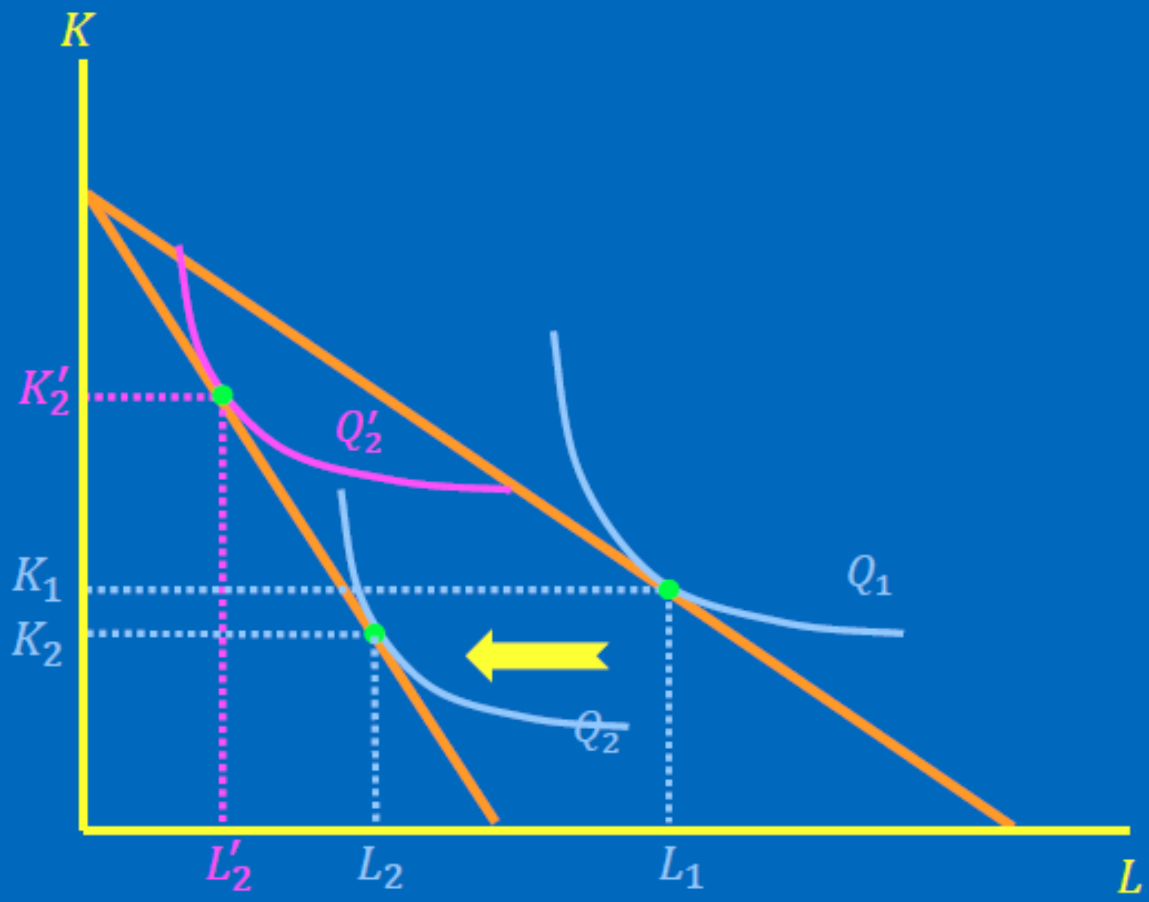


Left figure is based on provincial aggregate data. Right figure on the Large and Medium Enterprise data base. Note that Y/L growth exceeds real wage growth in the micro data only for the subset of the largest firms constituting about 2.5% of the total sample firms but nearly 60% of total physical capital.

Modeling Induced Innovation?

- Following J. R. Hicks (1932) (cited by Acemoglu and others), [factor-price] •••invention •••[is] directed to economizing the use of a factor which has become relatively expensive."
- Thus, wage-induced innovation would reduce the marginal product of labor (MPL) at given factor proportions.
- Analogously, an increase in the availability of physical capital would induce innovation to increase MPK.

Wage-Induced Innovation



Starting from initial equilibrium at point L_1,K_1 relative wage increases, and equilibrium moves to point L_2,K_2, with a higher K:L ratio. The higher unit cost of producing the lower output Q_2 compared with the original output Q_1 creates a profit opportunity leading to investment in new capital embodying labor-saving innovation which reduces MPL and raises MPK. Equilibrium after innovation is at L'_2 K'_2. Output at Q'_2 is greater than at Q_2 and labor productivity (output per unit of labor) increases further than under substitution alone.

Wage-Induced Innovation

- From Acemoglu, we specify the production function

$$Y = \alpha^{-\alpha}(1-\alpha)^{-1}(K^{\theta}L^{1-\theta})^{\alpha}q(\theta)^{1-\alpha}$$

To which we add a factor-neutral (TFP) term *A* :

$$Y = A\alpha^{-\alpha}(1-\alpha)^{-1}(K^{\theta}L^{1-\theta})^{\alpha}q(\theta)^{1-\alpha}$$

Where

- *Y* is output;
- *K* and *L* are physical capital and labor, respectively;
- *q(θ)* is the quantity of an intermediate good produced by a monopolist that embodies technology *θ*; and
- *A* is TFP as specified above.

Wage-Induced Innovation

In our empirical work, we rely mainly on the production function in intensive form:

Eqn (3)

$$\frac{Y}{L} = A^{1/\alpha}\alpha^{-1}(1-\alpha)^{-1}\left(\frac{\bar{K}}{L}\right)^{\theta}$$

which further derivation allows us to express in terms of the real wage, as

$$\frac{Y}{L} = \frac{1}{\alpha(1-\theta)}W$$

The detailed derivations are is available in the Appendix to our paper.

Wage-Induced Innovation

- Notice that in log form, the coefficient of W in $\frac{1}{\alpha(1-\theta)}W$ is unity.
- To identify the behavior of the technology parameter θ, we define $\phi = \ln\left(\frac{1}{\alpha(1-\theta)}\right)$ and divide both sides of of $\frac{Y}{L} = \frac{1}{\alpha(1-\theta)}W$ by W to obtain $\frac{Y}{L}\frac{1}{W} = \frac{1}{\alpha(1-\theta)}$
- Taking logs, we specify

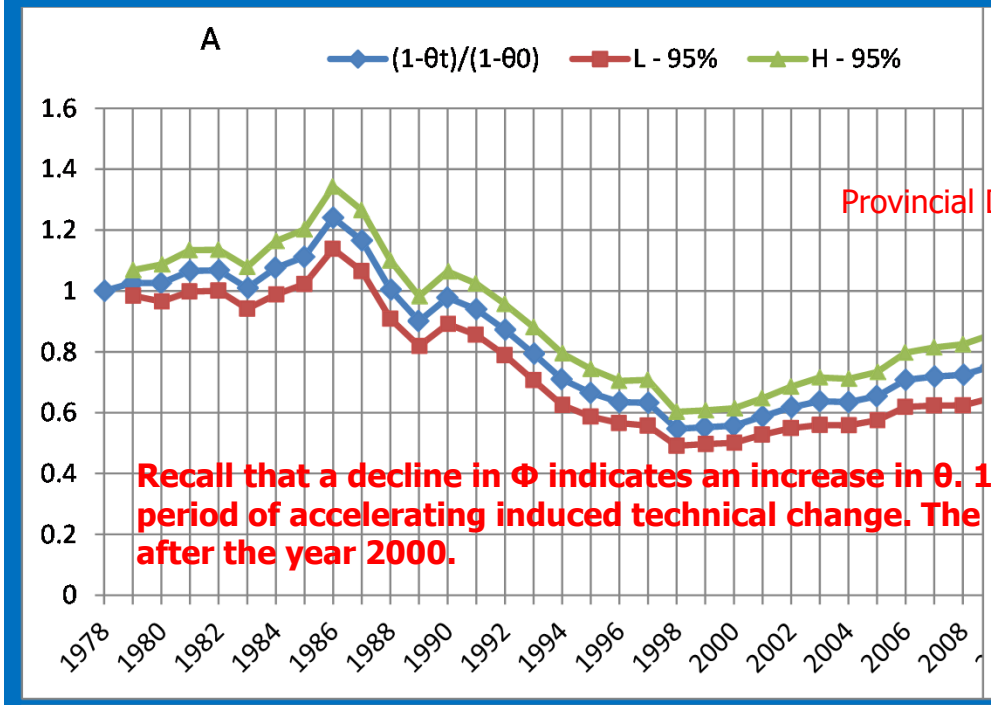
Eqn (4a) $$\ln\left(\frac{Y_{it}}{L_{it}}\frac{1}{W_{it}}\right) = \phi_t + \eta_i + \varepsilon_{it}$$

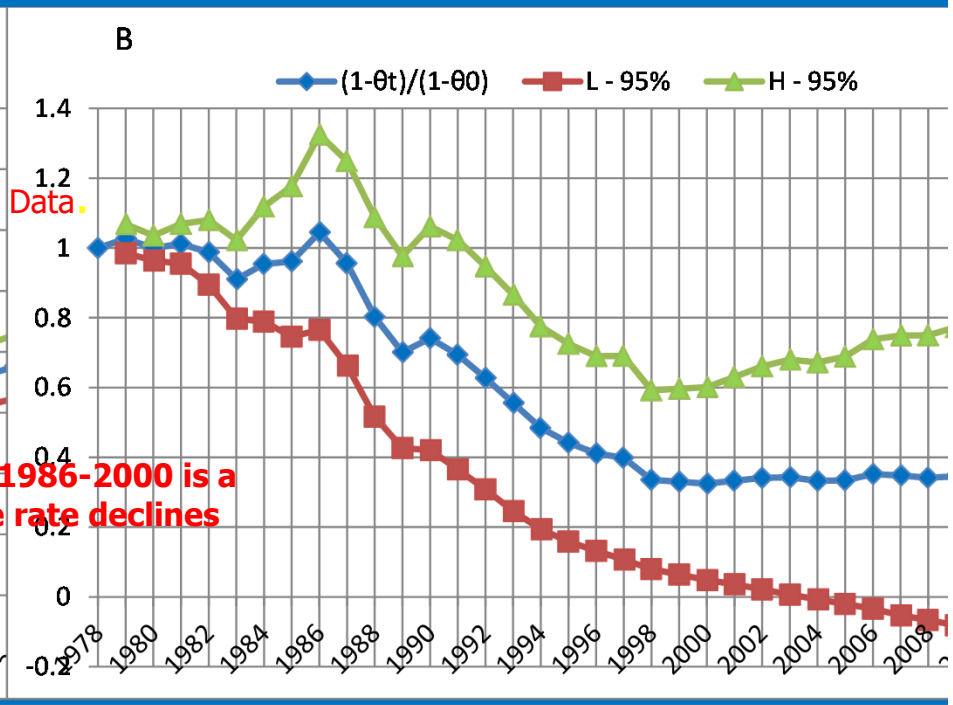
where Φ_t and η_i are region- and time-specific dummies, respectively.

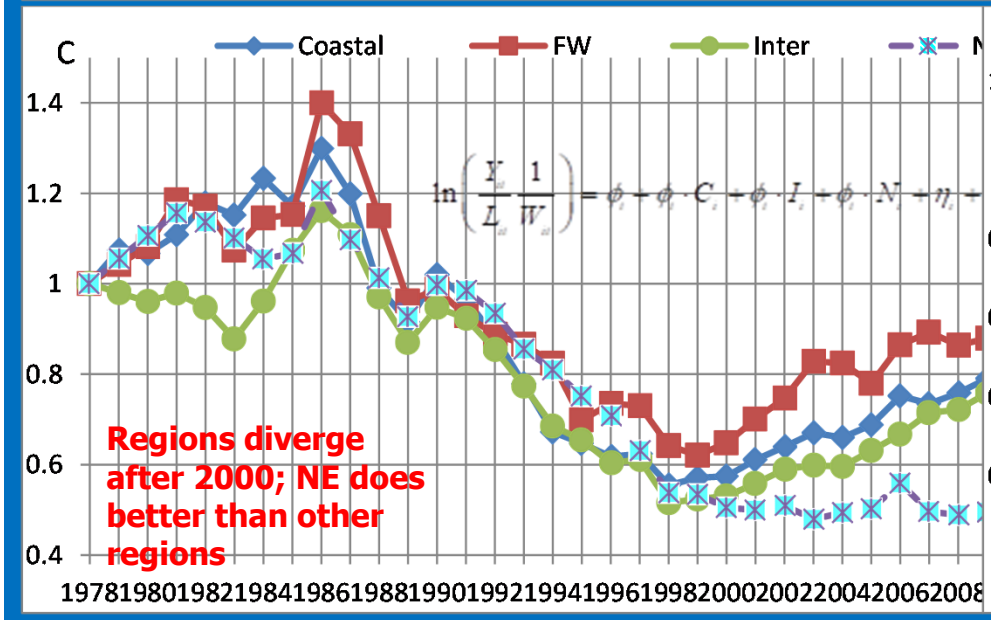
- To examine θ over time, From the estimates of Φ_t we calculate $\frac{1}{e^{\phi_t - \phi_0}} = \frac{1-\theta_t}{1-\theta_0}$.

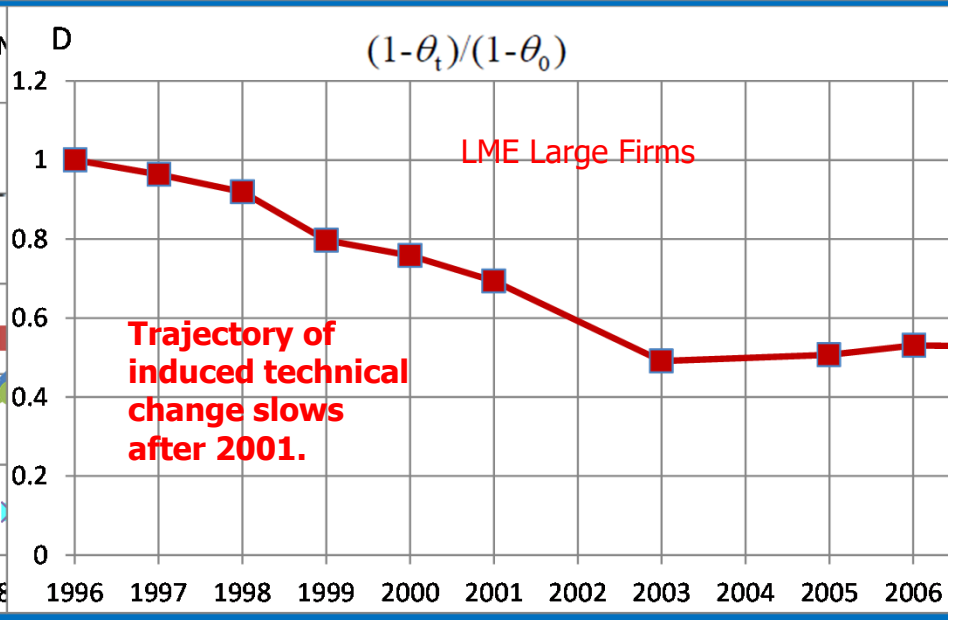
Under ongoing tech change, this ratio should be <1

Eq (4a) Estimation Results









Wage-Induced Innovation

- Under endogenous technical change, $\frac{\partial \theta}{\partial K} > 0 \text{ and } \frac{\partial \theta}{\partial W} > 0$.
- Thus, estimation of equation (4a) is vulnerable to omission of physical capital.
- To capture the impact of physical capital as well as wage we take logs of $\frac{Y}{L} = \frac{1}{\alpha(1-\theta)} W$ and obtain the approximation

Eqn (5) $$\ln\left(\frac{Y}{L}\right)_{it} = \alpha_{it} + \beta \ln W_{it} + \delta \ln K_{it} + \gamma Z_t + \lambda Z_t \ln W_{it} + \mu Z_t \ln K_{it} + \varepsilon_{it}$$

which we estimate with year fixed effects to capture changes in TFP over time. Z is a date in time. Hypotheses: (i) $\beta > 1$; (ii) $\delta > 0$. λ and μ are indicators of regime change over time.

Eq(5) Provincial Data. 2SLS; IV for W is 10-year lagged primary industry labor force. W coeff supports endogenous tech change but weak ID stat is not very high. Test for β =1 not strong. No evidence of change over time.

Secondary Industry Output:Labor Ratio Provincial Data Eqn 5

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Log Y/L	Log Wage	Log Y/L	Log Wage	Log Y/L~	Log Wage	Log Y/L~	Log Wage
Log Wage (t-1)	1.592**		1.663		1.650***		1.646***	
	(0.012)		(0.255)		(0.005)		(0.006)	
Log Secondary K Stock (t-1)	-0.130	0.0.088	-0.111	0.153***	-0.142	0.068	-0.149	0.064
	(0.295)	(0.170)	(0.622)	(0.001)	(0.194)	(0.332)	(0.179)	(0.344)
Log R&D Stock (t-1)					0.003	0.057	-0.040	0.027
					(0.987)	(0.369)	(0.822)	(0.669)
Log FDI Stock (t-1)							0.043	0.025
							(0.296)	(0.134)
Log Primary Emp. (t-10)		-0.219***		-0.156***		-0.238***		-0.226***
		(0.010)		(0.005)		(0.003)		(.005)
Post-2000 x Log Wage (t-1)			-0.000					
			(0.999)					
Post-2000 x Log Secondary K Stock (t-1)			-0.022					
			(0.749)					
Post-2000 x Log Primary Emp. (t-10)				-0.051***				
				(0.000)				
Constant	-13.252***	10.945***	13.998***	10.530***	-13.672***	10.788***	-13.928**	10.567***
	(0.035)	(0.000)	(0.143)	(0.000)	(0.018)	(0.000)	(0.016)	(0.000)
Observations	604							
R-squared	0.961		0.959		0.961		0.961	
Years	1991-2011							
Test Beta = 1 p-val	0.353		0.505		0.273		0.283	
Weak ID Stat	6.75		1.099		7.66		7.83	

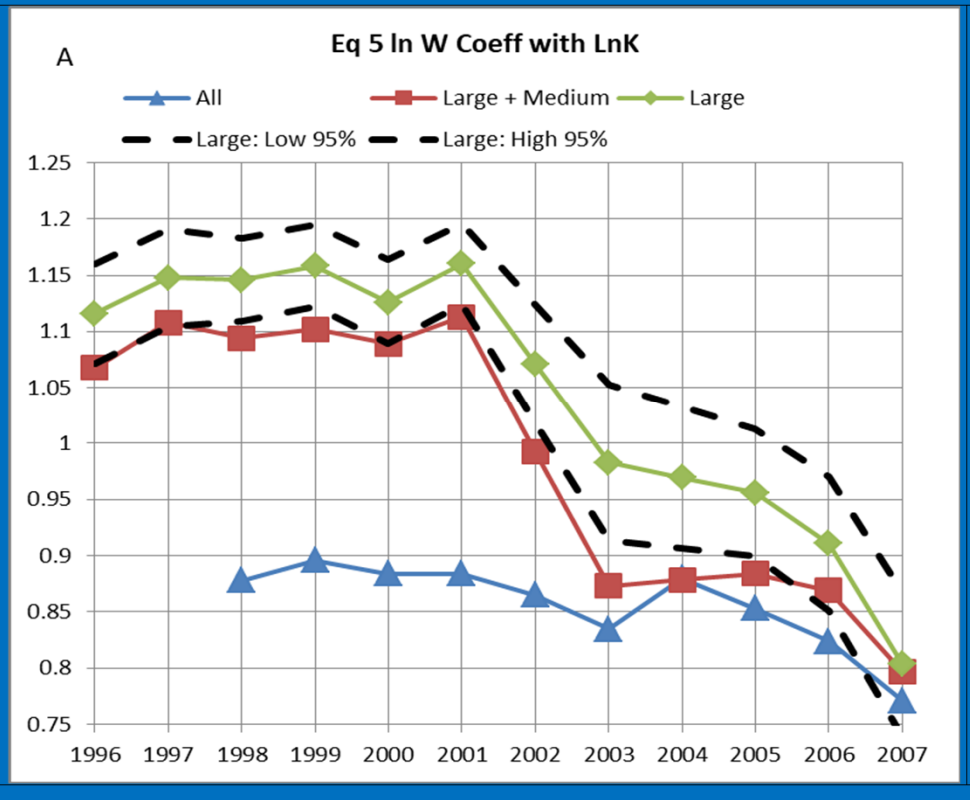
No evidence of impact of K on endog tech change

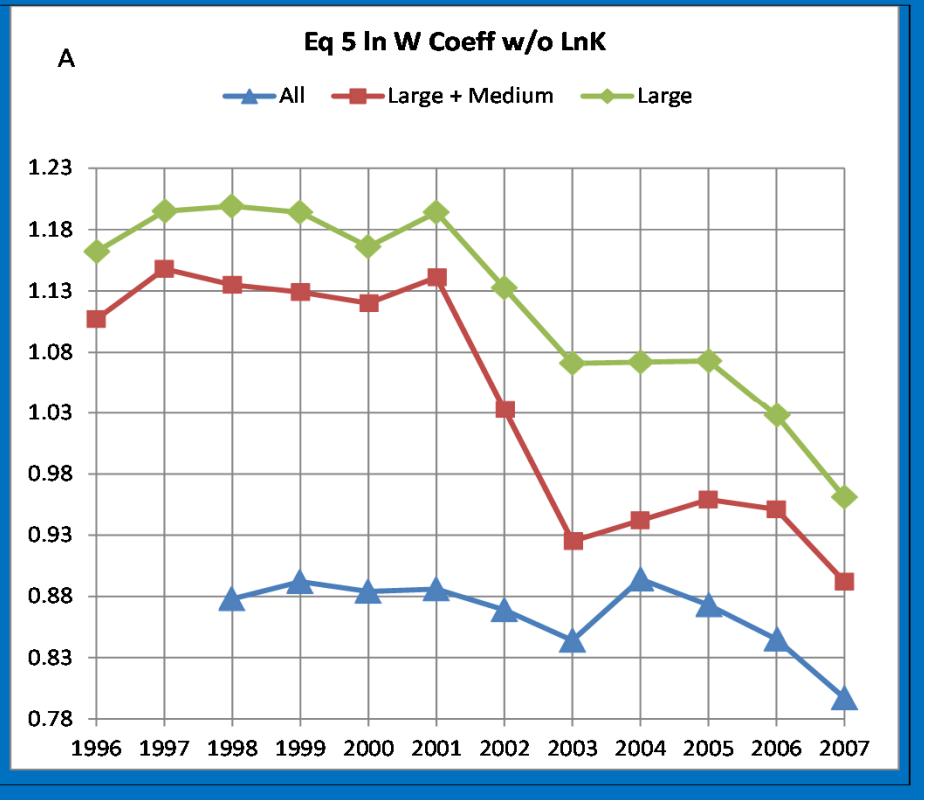
No evidence of impact of R&D or FDI holding W and K constant.

Estimates of β Eq (5) LME Data

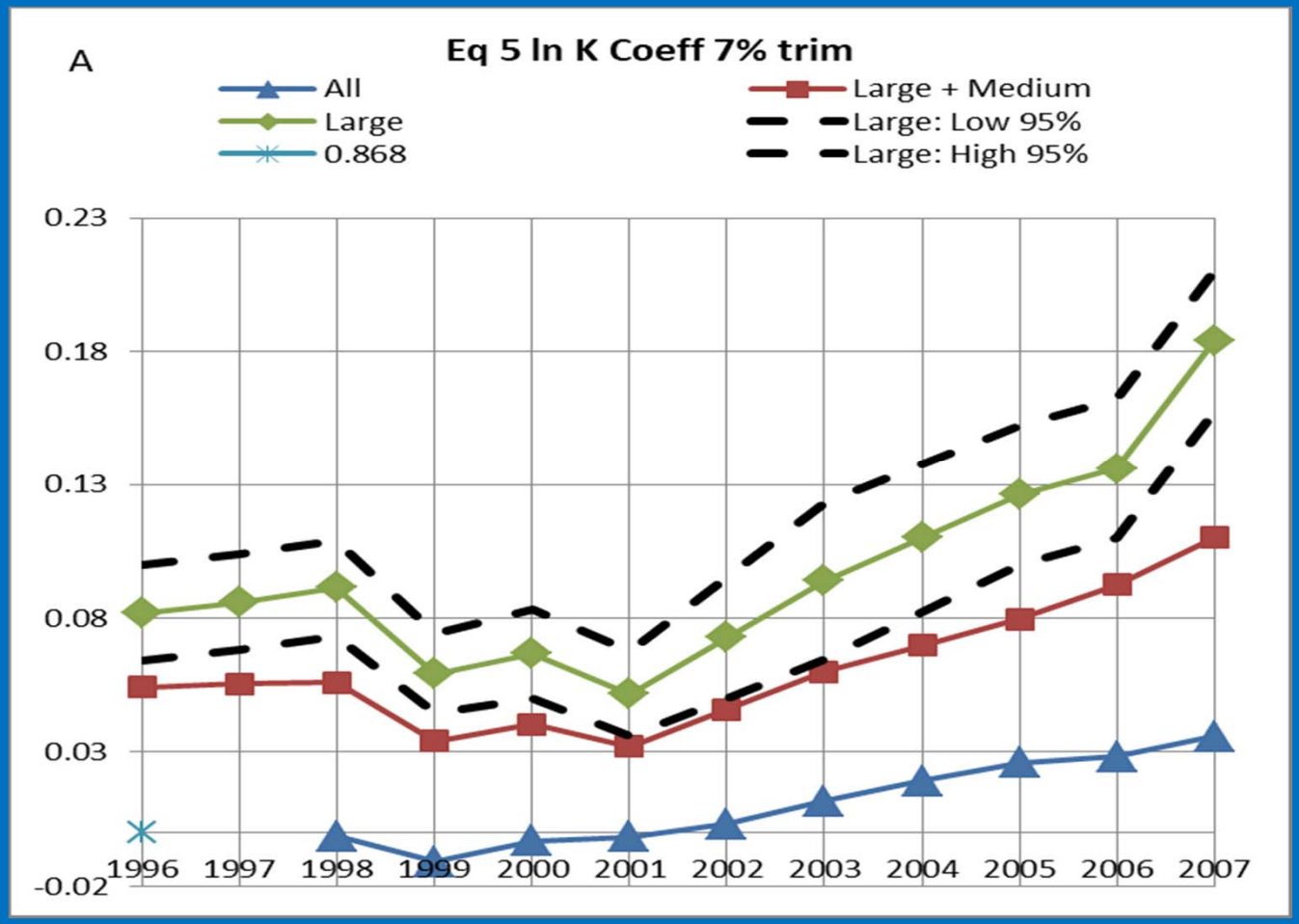
- Assume W and K exogenous in micro data
- Results robust to exclusion of LnK
- Large and Large+Medium samples show strong evidence of induced technical change through 2001.
  - Point estimate < 1 2003 and later.
- When smaller firms included (All Firms sample), coefficient of β < 1.

(Samples estimated with 2-tail 7% Trim based on wage share in value added)





Estimates of δ Eq (5) LME Data



The estimated coefficients are consistently positive for the two larger-firm LME samples, and above zero after the year 2000 for All Firms; reflect in reverse paths of β. Did constraints on accession to funds for financing investment in physical capital have stronger impacts on innovation after China's accession to WTO as lower-productivity firms needed to become more competitive ?

Modeling θ More Explicitly

Another perspective for estimating the relationship between labor productivity and the price of labor is developed by taking logs of (3) and adding location and date identifiers, to obtain

$$(6)\ \ln\left(\frac{Y}{L}\right)_{it} = \mathrm{B}_{it} + \theta \ln\left(\frac{\bar{K}}{L}\right)_{it} \quad \text{where}$$

$$\mathrm{B}_{it} = \frac{1}{\alpha}\ln A_{it} - \ln \alpha(1-\alpha)$$

To hold constant the influence of the availability of physical capital, and we specify: $\theta = \gamma_0 + \gamma_1 f(W) + \gamma_2 f(\bar{K})$

where $f(X) = \ln X$, obtaining

$$(7)\ \ln\left(\frac{Y}{L}\right)_{it} = B_{it} + \gamma_0 \ln\left(\frac{\bar{K}}{L}\right)_{it} + \gamma_1 f(W_{it}) \ln\left(\frac{\bar{K}}{L}\right)_{it} + \gamma_2 f(K_{it}) \ln\left(\frac{\bar{K}}{L}\right)_{it} + \varepsilon_{it}$$

Hypothesis iv: $\gamma_1 > 0$
Hypothesis v: $\gamma_2 > 0$

Eq(7) Provincial Data. 2SLS; IV for W is 10-year lagged primary industry labor force. W coeff supports endogenous tech change but K coeff rejects it. Weak ID stat is not very high. No evidence of change over time.

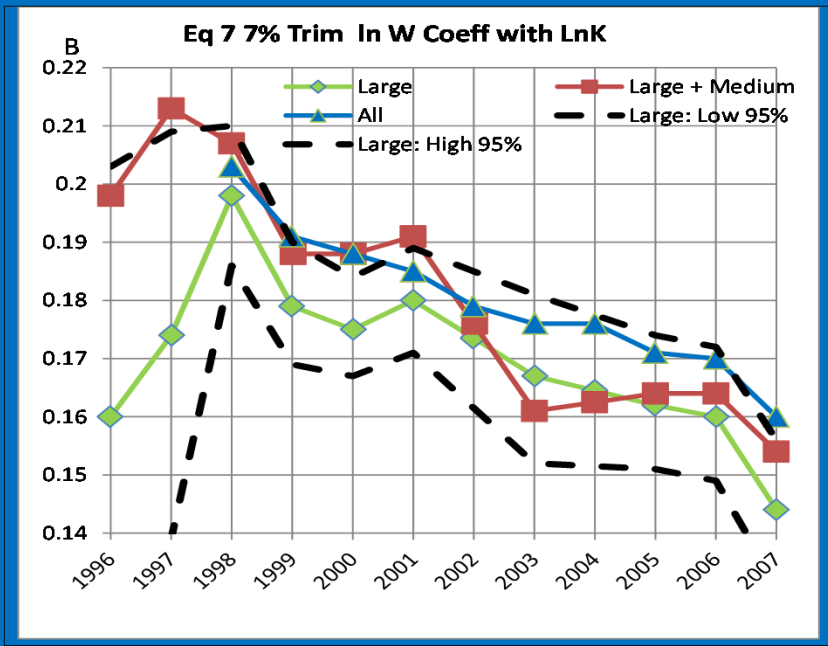
Perhaps the innovation gap between small and large firms obscures aspects of endogenous innovation in estimates based on the provincial aggregates.

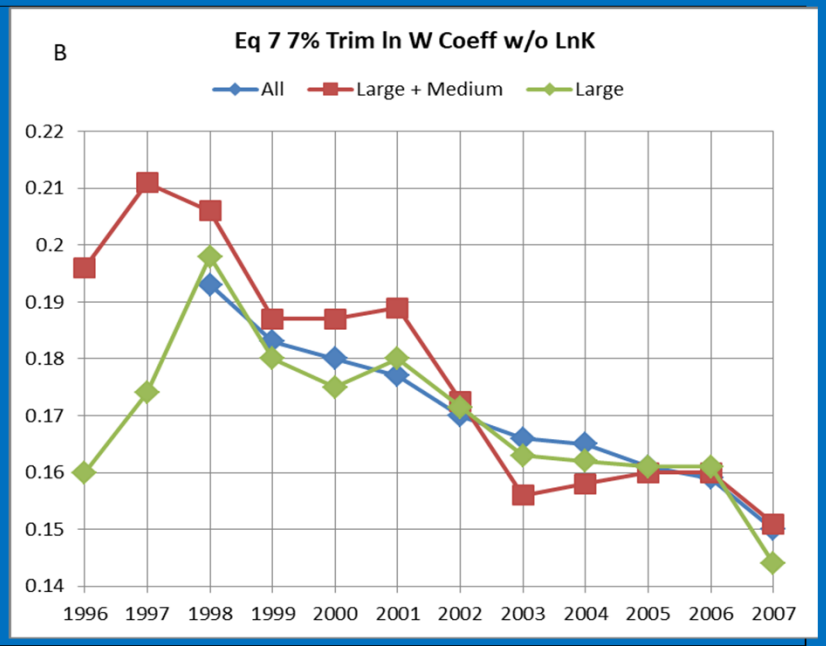
Secondary Industry Output:Labor Ratio Eqn 7 Provincial Data

	(1)	(2)	(3)	(4)	(5)
	Log Y/L	Log Wage	Log Y/L	Log Wage	Log Wage Post-2000
Log Wage (t-1) x Log K/L (t-1)	0.185**		0.131		
	(0.018)		(0.331)		
Log Primary Emp. (t-10) x Log K/L (t-1)		-0.318***		-0.068	0.085
		(0.007)		(0.566)	(0.329)
Log K/L (t-1)	0.659***	1.128***	0.790**	-0.528	-4.315***
	(0.000)	(0.004)	(0.027)	(0.163)	(0.000)
Log K Stock (t-1) x Log K/L (t-1)	-0.200***	1.034***	-0.168	1.051***	0.302***
	(0.003)	(0.000)	(0.114)	(0.000)	(0.003)
Post-2000 x Log Wage (t-1) x Log K/L (t-1)			-0.016		
			(0.858)		
Post-2000 x Log Primary Emp. (t-10) x Log K/L (t-1)				-0.181***	-0.336***
				(0.000)	(0.000)
Post-2000 x Log K/L (t-1)			0.079	1.969***	8.014***
			(0.884)	(0.000)	(0.000)
Post-2000 x Log K Stock (t-1) x Log K/L (t-1)			0.021	-0.090*	0.379***
			(0.614)	(0.080)	(0.000)
Constant	-0.168	6.437***	0.076	7.019***	6.953***
	(0.753)	(0.000)	(0.868)	(0.000)	(0.000)
Observations	642	642	604	604	604
R-squared	0.982		0.986		
Years	1991 - 2011		1991 - 2011		
Weak ID Stat	7.291		0.973		

Robust pval in parentheses
*** p<0.01, ** p<0.05, * p<0.1

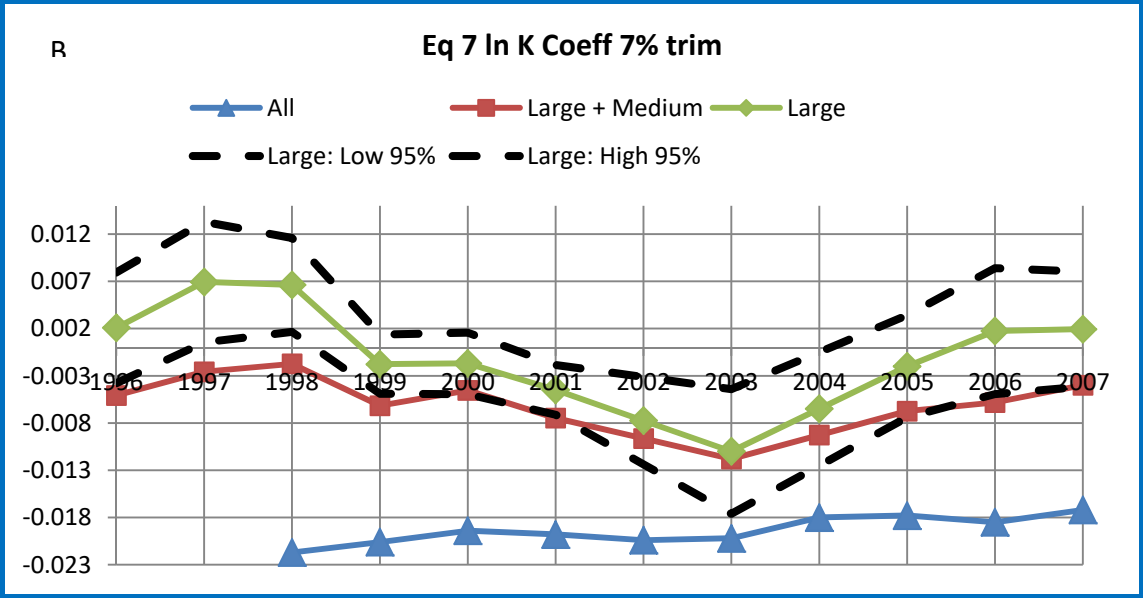
Eq (7) γ_1 LME Data





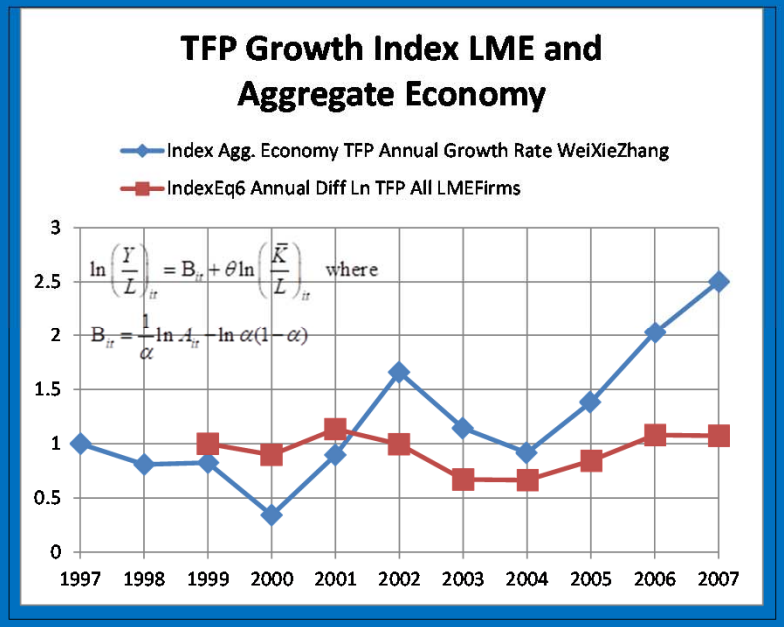
- Series are roughly similar to those for equation 5's β particularly for the Large and Medium and Large firm subsamples.
- Support hypothesis of wage-induced innovation in all years, but
- Both indicate a substantial fall-off in the degree of wage innovation over time with the decline beginning in 2001 in the equation (5) results and earlier, in 1998, in the equation (7) results.

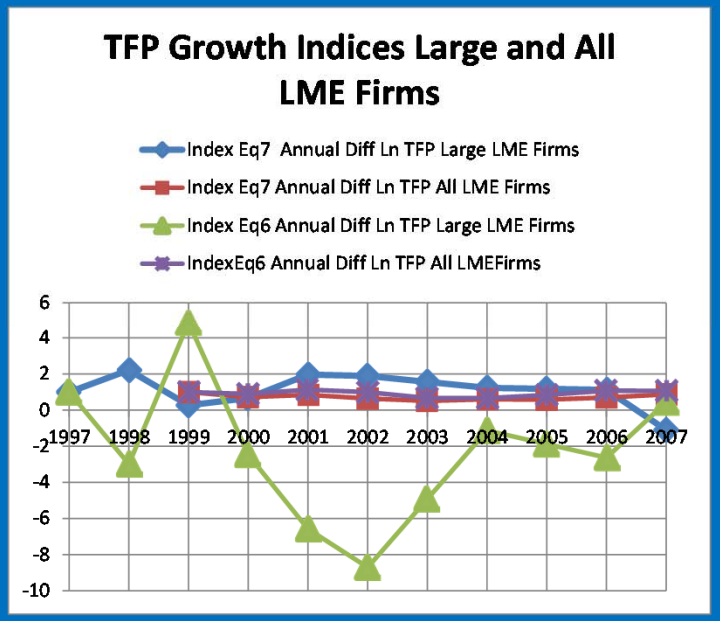
Eq (7) γ_2 LME Data



- In contrast to Eq (5), the estimated values of the ln K coefficient are positive only for the large-firm LME subset, and only for the years 1996-1998 and 2007.
- However, the estimates turn up after 2003, similar to that reported for δ in panel B, which turns up after 2001.
- The upward trend of the paths of δ for the two subsamples containing the larger LME firms again suggest that accession to funds to finance investment had greater impacts on innovation after China's accession to WTO forced lower-productivity firms to become more competitive if they were to survive in the international marketplace.

How do our estimates of endogenous innovation compare with TFP growth estimates?



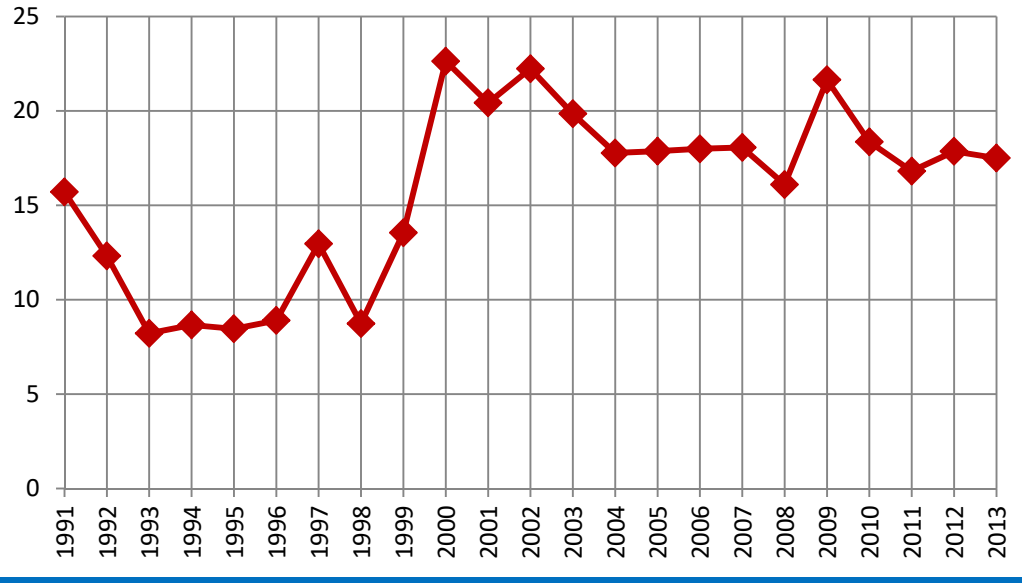


From Wei, Xie, & Zhang (2017) we calculate aggregate TFP growth and compare it to calculations using LME data for all firms.

TFP growth fell sharply in the two full years after China's WTO accession (2003 and 2004) before rising above its 2002 peak (among the large LME firms) and returning to its' pre-2003 level

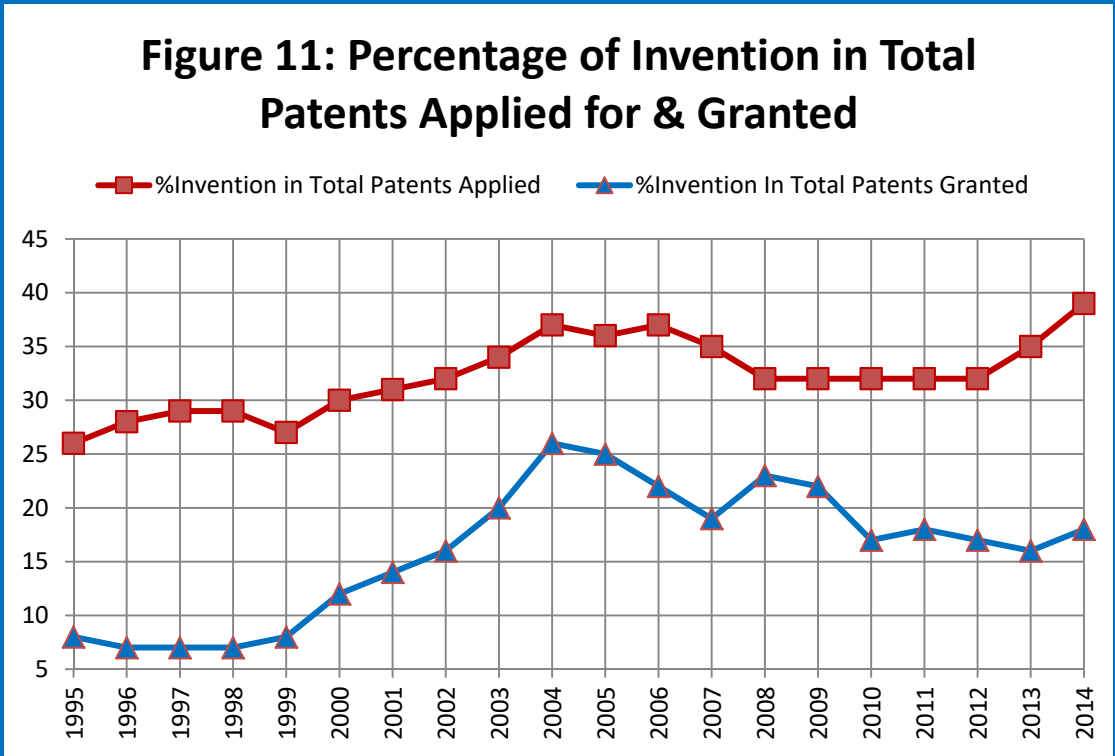
Indirect Innovation Indicators: R&D

Figure 10: Annual Growth of R&D Stock (%, assuming 20% Depreciation Rate)



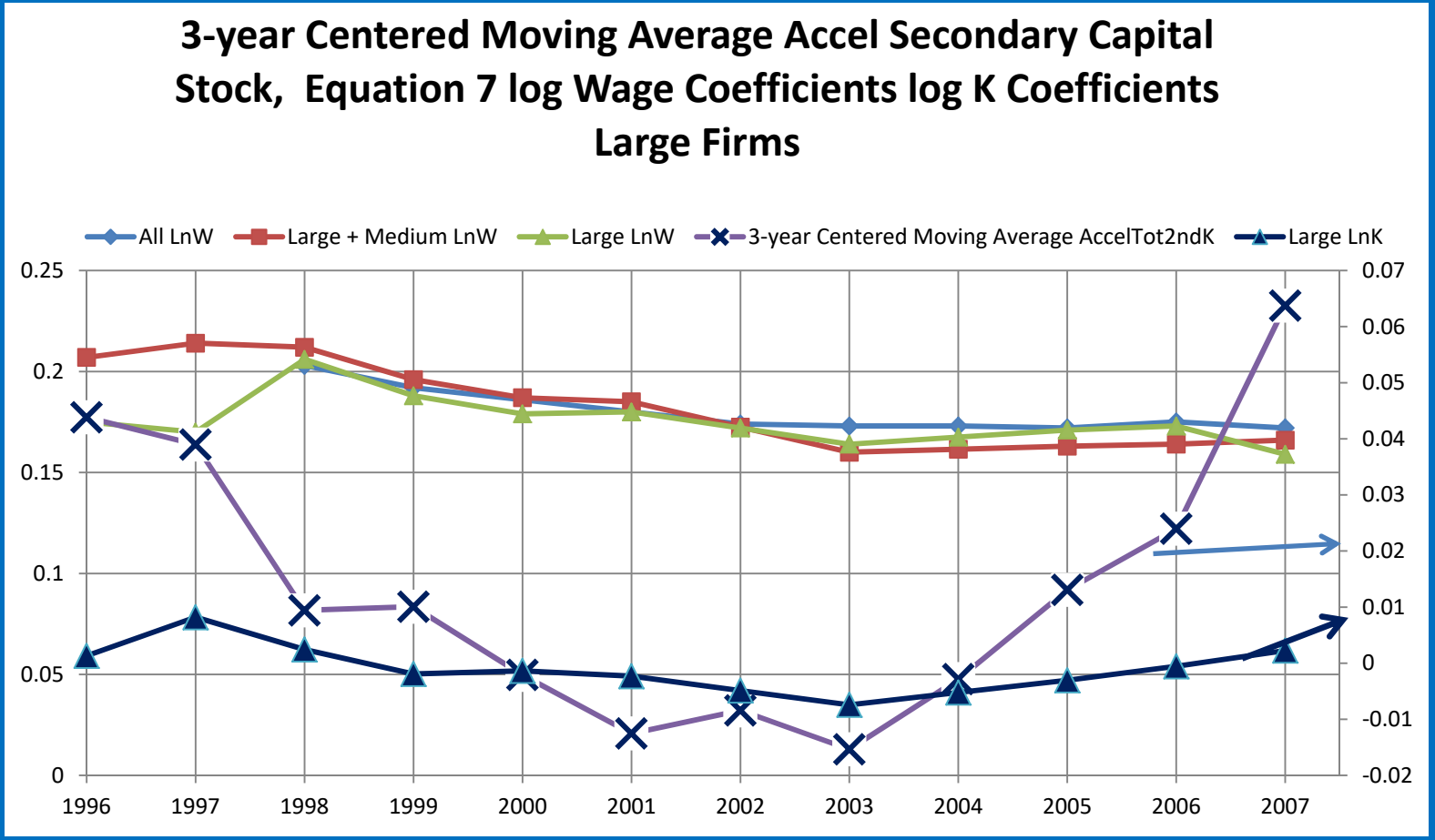
The R&D series surges between 1998 and 2000 and in the patent series between 1999 and 2004.

Indirect Innovation Indicators: Patents



- The proportion of invention patents in total patent applications grew from 25% to over 35% between 1995 and 2004.
- The percentage of invention in total patents granted grew more sharply, starting one year after the surge in the R&D stock.
- The leveling off of the two series after 2003 is broadly consistent with the decline in the series tracking wage-induced innovation from equations (5) and (7).

Other Innovation Indicators: Capital Growth



Conclusions and Implications

- Our empirical results, based mainly on firms in secondary industry, provide evidence to support wage-induced innovation.
- We find that induced innovation was concentrated among the largest firms, occurring during the period beginning in the mid-1990s and tapering off significantly after China's entry into WTO. Did the scramble to survive mask innovative activity?
- If the elasticity of substitution exceeds unity, then labor productivity growth will exceed wage growth even under fixed technology.
- Bai and Qian (2010),and Mallick (2012) find that that the elasticity of substitution between capital and labor in China is equal to or less than unity
- There is robust evidence of substantially reduced wage-induced innovation in the approximately five years following China's accession to WTO .