Lightning, IT Diffusion and Economic Growth across US States*

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Abstract: Empirically, a higher frequency of lightning strikes is associated with slower growth in labor productivity across the 48 contiguous US states after 1990; before 1990 there is no correlation between growth and lightning. Other climate variables (e.g., temperature, rainfall, and tornadoes) do not conform to this pattern. A viable explanation is that lightning influences IT diffusion: a higher frequency of ground strikes increases IT user costs and thereby slows the spread of IT. We find that lightning indeed slows IT diffusion, conditional on standard controls. Hence, an increasing macroeconomic sensitivity to lightning may be due to the increasing importance of digital technologies for the growth process.

Keywords: Climate; IT diffusion; economic growth
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1. Introduction

There is compelling evidence to suggest that climate and geography profoundly affected the historical growth record (Diamond, 1997; Olsson and Hibbs, 2005; Putterman, 2008; Asraf and Galor, 2008). Today, climate shocks, like changes in the timing or quantity of rainfall, still affect growth in poor countries (Dell et al., 2008). But are climate and geography also important in highly developed economies, where high-tech industry and services are dominant activities?

Some research suggests that geography is still a force to be reckoned with, even in rich places. Access to waterways, for instance, appears to matter (Rappaport and Sachs, 2003). However, a geographic characteristic that exhibits a *time-invariant* impact on prosperity is difficult to disentangle from other slow moving growth determinants that may have evolved under the influence of climate or geography. In particular, climate and geography quite possibly influenced the evolution of economic and political institutions.[1]

The present paper documents that a particular climate related characteristic – lightning activity – exhibits a *time-varying* impact on growth in the world's leading economy. Studying the growth process across the 48 contiguous US states from 1977 to 2007, we find no impact from lightning on growth prior to about 1990. However, during the post 1990 period there is a strong negative association: states where lightning occurs at higher frequency have grown relatively more slowly. What can account for an increasing macroeconomic sensitivity to lightning?

One may begin by noting that the 1990s was a period of comparatively rapid US growth; it is the period where the productivity slowdown appears to finally have come to an end. Furthermore, the 1990s is the period during which IT appears to have diffused throughout the US economy at a particularly rapid pace. In fact, IT investment is often seen as a key

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[1] Diamond's (1997) sweeping study argues that bio-geography affected the timing of the Neolithic revolution and ultimately the rise of the organized state. Bio-geography, according to Diamond, is an "ultimate" determinant of prosperity, but not a central "proximate" one; countries are not permanently "cursed". Similarly, an apparent impact from "diseases" (morbidity or mortality) on comparative development may be convoluting the impact from early property rights institutions in former colonies (Acemoglu et al, 2001); the impact of access to waterways, as detected in cross-country data, may also be related to the formation of institutions (Acemoglu et al., 2005).

explanation for the US growth revival (e.g., Jorgenson, 2001). On a state-by-state basis, however, the process of IT diffusion, measured by per capita computers and Internet users, did not proceed at a uniform speed.

Lightning activity may importantly have influenced the speed of IT diffusion across the US, for the following reason. Digital equipment is extremely sensitive to power disruptions; power fluctuations lasting less than 1/60th of a second are sufficient to damage solid state electronics like microprocessors in computers. Frequent disruptions therefore reduces the longevity of IT equipment, and thus increases the user cost of IT capital. In practice, lightning activity causes 1/3 of the total number of annual power disruptions in the US (Chisholm and Cummings, 2006). Accordingly, lightning activity may have slowed IT diffusion by increasing the cost of IT capital, thus hampering IT investment. Naturally, the "power problem" may be (partly) addressed, but only at a cost. The acquisition of surge protectors, battery back-up emergency power supply (so-called uninterruptable power supply, UIP) and the adoption of a wireless Internet connection will also increase IT user costs through the price of investment.[2]

Even though a link between lightning and IT diffusion is theoretically plausible, it does not follow that the link is economically important. Nor is it obvious that IT can account for the lightning-growth correlation.

We therefore also study the empirical link between lightning and the spread of computers and Internet across the US. We find that the diffusion of computers and the Internet has progressed at a considerably slower pace in areas characterized by a high frequency of lightning strikes. This link is robust to the inclusion of standard controls for computer diffusion (Caselli and Coleman, 2001). Moreover, lightning ceases to be correlated with growth post 1990, once controls for IT are introduced.

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[2] The arrival of the "digital age" signalled a dramatic increase in the need for reliable power supply. During more than a century the reliability of the electricity grid has rested at 99.9 %. This was sufficient when the economy was built around light bulbs and electric motors. But microprocessors and computer networks demand at least 99.9999 % reliability; this amounts to only seconds of allowable outages per year. See e.g. National Energy Technology Laboratory (2003).

While the lightning-IT-growth hypothesis thus seems well founded, other explanations cannot be ruled out *a priori*. First, one may worry that the correlation between growth and lightning is due to co-varying trends. As noted above, economic growth accelerated in the 1990s. If lightning too was trending during this period, the correlation may be spurious. However, as we document below, from 1906 onwards US aggregate lightning is stationary; on a state-by-state basis, we find the same for all save for two states. There is thus little evidence to suggest that lightning exhibits a long-run trend. Accordingly, the correlation between lightning and growth is unlikely to be spurious because of "common trends".

Second, it could be the case that lightning acts as a "stand-in" for other climate variables, which impact on growth for various reasons. As a result, we examine an extensive list of climate variables, including rainfall, temperature, and frequency of tornadoes. None of these variables impacts on the correlation between lightning and state-level growth rates. Nor does any other climate variable exhibit the kind of time-varying impact on growth that we uncover for lightning.

Third, the lightning-growth correlation could be picking up "deep determinants" of prosperity, which exhibit systematic variation across climate zones, just as lightning does. For instance, settler mortality rates, the extent of slavery and so forth. However, the correlation between lightning and growth is left unaffected by their inclusion in the growth regression.

In sum, we believe the most likely explanation for the lightning-growth correlation is to be found in the diffusion mechanism. Interestingly, the analysis therefore provides an example of how technological change makes economies increasingly sensitive to certain climate related circumstances. This finding is consistent with the "temperate drift hypothesis" (Acemoglu et al., 2002), which holds that certain climate related variables may influence growth in some states of technology, and not (or in the opposite direction) in others.

The paper is related to the literature that studies technology diffusion; particularly diffusion of computers and the Internet (e.g., Caselli and Coleman, 2001; Beaudry et al., 2006; Chin and Fairlie, 2007). In line with previous studies, we confirm the importance of human capital for the speed of IT diffusion. However, the key novel finding is that climate related circumstances matter as well: lightning influences IT diffusion. In this sense the paper complements the thesis of Diamond (1997), who argues for an impact of climate on technology diffusion. Yet whereas climate, according to Diamond, is important in the context of agricultural technologies, the present paper makes plausible that climate also matters to technology diffusion in high-tech societies.

The analysis proceeds as follows. In the next section we document the lightning-growth link. Then, in Section 3, we discuss likely explanations (IT diffusion, other forms of climatic influence, institutions and integration) for the fact that lightning correlates with growth from about 1990 onwards. Section 4 concludes.

2. Lightning and US growth 1977-2007

This section falls in two subsections. In Section 2.1 we present the data on lightning and discuss its time series properties. In particular, we demonstrate that lightning is stationary; and that, for panel data purposes, lightning is best thought of as a state fixed effect. Next, in Section 2.2, we study the partial correlation between lightning and growth across the US states.

2.1 The Lightning Data

The measure of lightning activity that we employ is the *flash density*, which captures the number of ground flashes per square km per year. We have obtained information about the flash density from two sources. The first source of information is reports from weather stations around the US. From this source we have yearly observations covering the period 1906-1995 and 40 US states. From about 1950 onwards we have data for 42 states. The second source of information derives from ground censors around the US. This data is *a priori* much more reliable than the data from weather stations.[3] In addition, it is available for all 48 contiguous states, but it only comes as an average for the period 1996-2005.[4]

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[3] Lightning events recorded at weather stations are based on audibility of thunder (i.e., these are basically recordings of thunder days), whereas ground sensors measure the electromagnetic pulse that emanates from lightning strikes (i.e., these are recordings of actual ground strikes). In the context of IT diffusion it is ground strikes that matter, and not lightning which may occur between clouds, say.

[4] Further details are given in the Data Appendix.

In order to understand the data better, we begin by studying its time series properties. Figure 1 shows the time path for *aggregate* US lightning over the period 1906-95.

>Figure 1 about here<

The aggregate flash density is calculated as the state-size weighted average over the 40 states with data for this extended period. Visual inspection suggests that there is no clear trend. More formally, to test whether lightning contains a stochastic trend, we use an augmented Dickey-Fuller (DF) test with no deterministic trend. Lag length is selected by minimizing the Schwarz information criterion with a maximum of five lags. For aggregate US lightning the optimal lag length is one and the DF statistic equals -4.516. Hence the presence of a unit root is resoundingly rejected.

At the state level the presence of a unit root is also rejected at the 5% level in 38 of the 40 states, cf. Table 1. In light of the fact that DF tests have low power to reject the null of a unit root, we are in all likelihood safe to conclude that state-level lightning is also stationary.

>Table 1 about here<

These findings are of some independent interest in that they suggest that global warming has not interfered with the evolution of lightning trajectories in the US in recent times. In other words, there is little basis for believing that the flash density has exhibited a secular trend during the last century.

In the analysis below we focus on the period from 1977 onwards, dictated by the availability of data on gross state product. Consequently, it is worth examining the time series properties of the lightning variable during these last few decades of the 20th century.

During this period the flash density is for all practical purposes a fixed effect. In the Appendix we show state-by-state that the residuals obtained from regressing lightning on a constant are serially uncorrelated. That is, deviations of the flash density from time averages are, from a statistically perspective, white noise. To show this formally, we use both the Breusch-Godfrey test and a Runs test for serial correlation. By the standards of the Breusch-Godfrey test, we cannot reject the null hypothesis of no serial correlation in 38 states out of 42 states; using the Runs test, we fail to reject the null in 40 states. Importantly, no state obtains a p-value below 0.05 in both tests. This suggests that for the 1977-95 period lightning is best described as a state fixed effect.

As remarked above, we have an alternative source of data available to us, which contains information for the 1996-2005 period. How much of a concurrence is there between data for the 1977-95 period and the data covering the end of the 1990s and early years of the 21st century? Figure 2 provides an answer. Eyeballing the figure reveals that the two measures are very similar. In fact, we cannot reject the null that the slope of the line is equal to one. This further corroborates that lightning is a state fixed effect.

>Figure 2 about here<

From a practical perspective these findings have induced us to rely on the data deriving from ground censors in the analysis below. As noted above, this latter lightning data is of a higher quality compared to the measure based on weather stations and it covers more US states. Moreover, since deviations from the average flash density are white noise, we lose no substantive information by resorting to a time invariant measure. Still, it should be stressed that using instead the historical lightning measure based on weather stations (or combining the data) produces the same qualitative results as those reported below. These results are available upon request.

The cross-state distribution of the 1996-2005 data is shown in Figure 3, whereas summary statistics for 1996-2005 are provided in Table 2.

>Figure 3 about here<
>Table 2 about here<

There is considerable variation in the flash density across states. At the lower end we find states like Washington, Oregon and California with less than one strike per square km per year. It is interesting to note that the two states who are world famous for IT, Washington and California, are among the least lightning prone. At the other end of the spectrum we find Florida, Louisiana and Mississippi with seven strikes or more. It is clear that lightning varies systematically across climate zones. Hence, it is important to check, as we do below, that lightning's correlation with growth is not due to other climate variables like high winds, rainfall and so on.

2.2 The Emergence of a Lightning-Growth Nexus

Figures 4 and 5 show the partial correlation between growth in labor productivity and the flash density, controlling only for initial labor productivity.

>Figures 4 and 5 about here<

We have data on gross state product (GSP) per worker for the period 1977-2007.[5] Hence, for this first exercise we have simply partitioned the data into two equal sized 15 year epochs. As seen from the two figures, there is a marked difference in the partial correlation depending on which sub-period we consider. During the 1977-92 period there is no association between growth and lightning; the (OLS) point estimate is essentially nil. However, in the second sub-period the coefficient for lightning rises twenty fold (in absolute value) and turns statistically significant; places with higher flash density have tended to grow at a slower rate during the 1990s and the first decade of the 21st century.

While this exercise is revealing, there is no particular reason to believe that the lightning-growth correlation emerged precisely in 1992. Hence, to examine the issue in more detail, we study the same partial correlation by running "rolling" regressions over 10 year epochs, starting with 1977-87.[6] That is, we estimate an equation of the following kind:

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[5] State level data on personal income is also available, and for a longer period. But personal income does not directly speak to productivity. By contrast, GSP per worker is a direct measure of state level labor productivity. Moreover, the GSP per worker series is available in constant chained dollar values, which is an important advantage in the context of dynamic analysis. See the Data Appendix for a description of the GSP per worker series.

[6] The exact choice of time horizon does not matter much; below we run regressions with 5, 10 and 15 year epochs that complement the present exercise.

$$\log\left(\frac{y_{it}}{y_{it-10}}\right) = b_0 + b_1 \log(y_{it-10}) + b_2 \log(\text{lightning}_i) + \varepsilon_{it},$$

and examine the evolution of b_2 as t increases. Figure 6 shows the time path for b_2 as well as the associated 95% confidence interval.

>Figure 6 about here<

In the beginning of the period there is not much of a link between lightning and growth; if anything the partial correlation is positive. As one moves closer to the 1990s the partial correlation starts to turn negative and grows in size (in absolute value). By 1995 the lightning-growth correlation is statistically significant at the 5% level of confidence. As one moves forward in time the partial correlation remains stable, and significant. Hence, this exercise points to the same conclusion as that suggested by Figures 4 and 5: the negative partial correlation between lightning and growth emerged in the 1990s.

Albeit illustrative, both exercises conducted so far are *ad hoc* in the sense that they do not allow for a formal test of whether the impact from lightning is rising over time. Hence, as a final check, we run panel regressions with period length of 5, 10 and 15 years. The results are reported in Table 3 below.

>Table 3 about here <

Since lightning, for all practical purposes, is a fixed effect (cf. Section 2.1), Table 3 reports the results from running pooled panel regressions. Specifically, we estimate the following equation:

$$\log\left(\frac{y_{it}}{y_{it-T}}\right)\left(1/T\right) = b_0 + b_1 \log(y_{it-T}) + b_{2t} \log(\text{lightning}_i) + \mu_t + \varepsilon_{it},$$

where T=5, 10, 15 and b_{2t} accordingly is allowed to vary from period-to-period by way of interaction with time dummies. This way we can track the statistical and economic significance of lightning over time. Note also that we include time dummies independently of lightning, so as to capture a possible secular trend in growth over the period in question.

Turning to the results we find that the impact of lightning increases over time, and turns statistically significant during the 1990s.[7] The significance of lightning is particularly noteworthy as it is obtained for the relatively homogenous sample of US states. As is well known, the growth process for this sample is usually fairly well described by the initial level of income alone, suggesting only modest variation in structural characteristics that impinge upon long-run labor productivity (e.g., Barro and Sala-i-Martin, 1992). As a result, the scope for omitted variable bias contaminating the OLS estimate for lightning is *a priori* much more limited than, say, in a cross-country setting. However, in the next section we do find that one particular growth determinant renders lightning insignificant: IT penetration.

The impact from lightning is *economically* significant as well. Consider the results pertaining to the "intermediate case", which involves 10 year epochs. Taken at face value, the point estimate for the 1990s imply that a one standard deviation increase in lightning intensity (about 2.4 flashes per year per sq km) induces a reduction in growth by about 0.2 percentage points $(\approx 0.2 \cdot \log(2.4))$, conditional on the level of initial labor productivity and the time effects. This is about 12.5 % of the gap between the 5th percentile and the 95th percentile in the distribution of GSP per worker growth rates for the period 1977-2007 (for the 48 states in our sample). By extension, variation in lightning by four standard deviations (roughly equivalent to moving from the 5th percentile to the 95th percentile in the lightning distribution across US states) can account for about 50% of the "95/5" growth gap.[8] Needless to say, this is a substantial effect.

These results uniformly support the same qualitative conclusion: a macro economic sensitivity to lightning has emerged over time in the US. The question is why?

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[7] The general time dummies (not reported) corroborate the prior of a revitalization of productivity growth during the 1990s.

[8] Log normality of lightning is not accurate; but on the other hand not terribly misleading either. It does exaggerate the actual variation in lightning slightly; the observed variation is about 7 flashes, compared to the "back-of-the-envelope" calculation implying roughly 9.

3. Hypotheses and Explanations

3.1. IT Diffusion

We begin this section by examining the theoretical foundation behind the claim that lightning (or, more appropriately, the flash density) should have an impact on growth via IT diffusion. Subsequently we examine the hypothesis empirically.

Theory: The simple analytics of why lightning matters to IT diffusion. The simplest way to think about IT diffusion is via basic neoclassical investment theory. That is, IT diffusion occurs in the context of IT capital *investments*. In what follows we develop a simple model that links the flash density (our independent variable in the regressions above) to IT capital accumulation, and thus IT diffusion and growth in output.

Consider a representative firm producing output, Y, with the technology F(C). C is the stock of IT capital, whereas F(•) is a neoclassical production function, featuring positive and diminishing returns; for simplicity we ignore other inputs in production. The price of output is normalized to one, and markets are competitive.

We assume the capital stock cannot be adjusted to its optimal level instantaneously. A reason would be the presence of (convex) installation costs. For simplicity, we ignore adjustment costs in the formal analysis, and assume instead that the IT capital stock simply follows an *ad hoc* adjustment rule capturing whatever frictions that prevent firms from adjusting the capital stock fully.[9]

Specifically, assuming time is continuous, the adjustment rule is $\dot{C} = \lambda \cdot (C^* - C)$, where $\dot{C} (= dC/dt)$ is the instantaneous change in the capital stock, λ is a positive parameter, C* is the optimal IT capital stock (to be determined below), and C is the current (or initial) stock of IT capital. Hence, in each period the capital stock is mechanically adjusted towards its optimal level.

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[9] Nothing much is lost by this simplification. The key result obtained below, that the flash density reduces growth, can also be derived invoking convex costs of adjustment, at the costs of more algebra. In the interest of brevity, however, we stick with the simpler model.

In the absence of convex adjustment costs the optimal IT capital stock, C*, is given by the first order condition from the static profit maximization problem:

$$F'(C^*) = u,$$

where *u* is the user cost of capital. Ignoring taxes, the user cost formula is (Hall and Jorgenson, 1967):

$$u = p(r + \delta - \pi),$$

where p is the relative investment price, r is the real rate of return, δ is the depreciation rate of IT capital, and π is the instantaneous rate of change in the relative investment price.

Next, we assume the depreciation rate is increasing in the number of lightning strikes, n, in the surrounding area of the power conductor. That is,

$$\delta = \delta(n),\ \delta'(n) > 0.$$

The basic idea is that lightning strikes lead to power disturbances, which reduce the longevity of IT capital. This assumption has a sound physical foundation. Solid-state electronics, such as computer chips, is constructed to deal with commercial power supply in the form of alternating current. The voltage of the current follows a sine wave with a specific frequency and amplitude. If the sine wave changes frequency or amplitude, technically, this constitutes a power disruption. Digital devices convert alternating current to direct current with a much reduced voltage; digital processing of information basically works by having transistors turn this voltage on and off at several gigahertz (Kressel, 2007). If the power supply is disrupted, then the conversion process may be corrupted; this is what causes damage to the equipment, reducing its longevity. It is important to appreciate that even extremely short lasting power disruptions are potentially problematic. Voltage disturbances measuring less than one cycle (i.e., 1/60th of a second, in the US case) are sufficient to crash and/or destroy servers, computers and other microprocessor-based devices (Yeager and Stalhkopf, 2000; Electricity Power Research Institute, 2003). A natural phenomenon which damages digital equipment, by producing power disruptions, is lightning activity (e.g., Shim et al., 2000, Ch. 2; Chisholm, 2000). In reduced form then, more lightning strikes to the power supply implies higher IT capital depreciation.[10]

Finally, the number of strikes, n, per year (per 100 km line length) can be determined as (Chisholm, 2000):

$$n = 3.8 \cdot f \cdot h^{0.45},$$

where f is the *flash density* and h is the height (in meters) of the conductor above ground. This completes the model.

To see how the flash density impacts on IT diffusion, substitute n into the user cost expression, and invoke the first order condition from profit maximization. Then the optimal IT capital stock, C*, is given by

$$C^* = \Phi\left\{p\left[r + \delta\left(3.8 \cdot f \cdot h^{0.45}\right) - \pi\right]\right\},$$

where $\Phi \equiv F'^{-1}$. As a consequence, using the adjustment rule, the growth rate of the IT capital stock becomes

$$\frac{\dot{C}}{C} = \lambda \cdot \frac{\Phi\left\{p\left[r + \delta\left(3.8 \cdot f \cdot h^{0.45}\right) - \pi\right]\right\}}{C} - \lambda.$$

This expression forms the basis for the following observation:

Proposition: *Conditional on the initial capital stock, a higher flash density leads to a lower growth rate of the IT capital stock*.

Proof: Since $\Phi' < 0$, $\delta' > 0$ and λ > 0, the result follows immediately from differentiation. QED

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[10] Note that lightning may enter a firm or household in four principal ways. First, lightning can strike the network of power, phone, and cable television wiring. This network, particularly when elevated, acts as an effective collector of lightning surges. The wiring conducts the surges directly into the residence, and then to the connected equipment. In fact, the initial lightning impulse is so strong that equipment connected to cables up to 2 km away from the site of the strike can be damaged (BSI, 2004). Technically speaking, this is the mechanism we are capturing in the simple model above. Second, when lightning strikes directly to or nearby air conditioners, satellite dishes, exterior lights, etc., the wiring of these devices can carry surges into the residence. Third, lightning may strike nearby objects such as trees, flagpoles, road signs, etc., which are not directly connected to the residence. When this happens, the lightning strike radiates a strong electromagnetic field, which can be picked up by the wiring in the building, producing large voltages that can damage equipment. Finally, lightning can strike directly into the structure of the building. This latter type of strike is extremely rare, even in areas with a high lightning density.

Hence, in areas with a greater flash density, the speed of IT diffusion - as measured by IT capital accumulation - will proceed at a slower pace. The intuition is that a higher flash density rate increases the frequency of power disturbances, IT capital depreciation, the user cost of IT capital, and thus lowers IT investments. Moreover, as output is increasing in the IT capital stock, Y=F(C), growth in output will similarly tend to be slower in areas with greater lightning activity, conditional on the initial level of output.[11]

It is worth reiterating that firms may take pre-emptive actions so as to reduce the impact of lightning on the cost of capital; this could done by investing in surge protectors, say. However, the crux of the matter is that this imposes an additional cost to be carried in the context of IT investments; in terms of the model above, it amounts to an increasing investment price, *p*. Hence, even if we take the likely "pre-emptive measures" into account, more lightning prone areas will tend to feature slower growth in IT capital, and thus slower output growth.

The above considerations are likely to become increasingly important over time for understanding cross-state growth performance, for a couple of reasons. First, IT capital investments accounted for a substantial part of output growth, starting in the 1990s (e.g., Jorgenson, 2001). Consequently, factors that impact on IT capital accumulation (e.g., the flash density) should also become more important to growth. Second, the 1990s was the era during which the Internet emerged (in the sense of the World Wide Web); a conceivable reason why firms chose to intensify IT investments during the same period. [12] From a physical perspective, however, the network connection is another way in which lightning strikes may reach the computer, in the absence of wireless networks (which have not been widespread until very recently). Third, the 1990s saw rapid increases in the computing power of IT equipment. In keeping with Moore's law, processing speed doubled roughly every other year. This is an important propagation mechanism of the lightning-IT investment link. The reason is

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[11] It should be clear that the advocated mechanism is robust in a general equilibrium setting. Through elevated capital depreciation, higher lightning density would work to reduce the long-run (steady state) level of capital per worker in any neoclassical growth model. Hence, conditional on the initial capital stock, growth will be reduced in transition by an increasing flash density.

[12] The WWW was launched in 1991 by CERN (the European Organisation for Nuclear Research). See Hobbes. Internet Timeline v8.2 <http://www.zakon.org/robert/internet/timeline/> .

that the sensitivity of computers to small power distortions *increases* with the miniaturization of transistors, which is the key to increasing speed in microprocessors (Kressel, 2007).

In sum, these developments would all contribute to increasing the importance of the flash density to IT investments, and thus to growth, during the 1990s. But the question is whether empirically this theory can account for the apparent increasing macroeconomic sensitivity to lightning.

Empirical analysis: Lightning, IT diffusion and Economic Growth. In order for the above theory to be able to account for the lightning-growth correlation, two things need be true. First, it must be the case that lightning is a strong predictor of IT across the US states. Second, there should be no explanatory power left in lightning vis-à-vis growth, once we control for IT. We examine these two requirements in turn.

In measuring the diffusion of IT capital across the US we employ two measures. Both measures derive from a supplement to the 2003 Current Population Survey, which contained questions about computer and Internet use. The first measure is percentage of households with access to Internet, and the second measure is percentage of households with a PC. A couple of remarks on these data are necessary.

First, we only have *one* observation for both IT variables. Consequently, we have to settle for cross section regressions. Second, one may question whether there is value in using both variables, since having access to a computer is a prerequisite for the use of the Internet. Yet, the emergence of the WWW is a much more recent technology than the PC, as the former derives from 1991. The personal computer started spreading earlier. Hence, the initial conditions that may matter to the speed of adoption are discernible by time. For instance, whereas educational attainment in the 1970s should influence the spread of the personal computer, the Internet is affected by education levels in the 1990s. Hence, the two empirical models of IT diffusion will have to differ in terms of the "dating" of the right hand side IT diffusion determinants. As a result, we employ both.

A natural point of departure is with the simple correlation between the flash density and the two IT measures for the 48 states in our sample. Figure 7 and 8 depicts them.

>Figures 7 and 8 about here<

Visually, the strong negative correlations between the flash density and PC and Internet users, respectively, are immediately obvious. By 2003, states that experience lightning strikes at a higher frequency also have relatively fewer users of computers and the Internet.

A more systematic approach involves more controls of course. Human capital is probably the first alternative determinant of diffusion that comes to mind. The idea that a more educated labor force is able to adopt new technologies more rapidly is an old one, going back at least to the work of Nelson and Phelps (1966). Another natural control is the level of GSP per worker. Aside from being a catch-all control for factors that facilitate diffusion, it can also be motivated as a measure of the "distance to the frontier". *A priori* the sign of the coefficient assigned to GSP per worker is therefore ambiguous. A positive sign is expected if initially richer areas are able to acquire IT equipment more readily. A negative sign could arise if richer areas, by closer proximity to the technology frontier, are less able to capitalize on "advantages of backwardness".

In addition to labor productivity and human capital, we follow Caselli and Coleman (2001) in choosing relevant additional determinants of IT diffusion (they also include human capital and income per capita). First, we use measures for the composition of production; it seems plausible that IT may spread more rapidly in areas featuring manufacturing rather than agriculture. Second, we employ proxies for global links, measured by international movements of goods and capital, and a measure of local market size: state population. Third, we employ various historical variables as controls. Caselli and Coleman, studying cross-country data, include a measure of economic institutions, which we are not able to do directly in our US sample. However, by including various plausible historical determinants of productivity (like, soldier mortality, the pervasiveness of slavery in the late 19th century and so on) we may hope to be able to pick up the same type of information.[13] Of course, in a US context one would *a priori* expect cross-state differences in institutional quality to be orders of magnitude smaller than in cross-country data.

>Tables 4 and 5 about here<

In Table 4 we report the results for Internet users; Table 5 contains similar regressions for personal computers. Since PCs emerged in the 1980s we measure the determinants of PC diffusion around 1980 whenever feasible. By contrast, since the WWW emerged in 1990, we measure the same initial conditions around 1990.

In column 1 of Table 4 we examine the simple correlation between Internet users and the flash density; the latter is highly significant and can account for nearly 40% of the variation in Internet users as of 2003. In the next 6 columns we include GSP per worker in 1991 along with various human capital measures. As is clear, most of the human capital variables are highly significant, along side GSP per worker and the flash density. This is consistent with previous findings (e.g., Caselli and Coleman, 2001; Beaudry et al., 2006). Still, the best fit is obtained when we employ the fraction of state population with a high school diploma or more (Column 4); along with the flash density and (log) GSP per worker the three variables can account for ¾ of the variation in Internet users.

In an effort to check for robustness the next ten columns (8-17) introduce the auxiliary controls (on top of human capital, income and lightning), one by one. In none of these cases is the influence from the flash density eliminated. Rather, the point estimate appears robust to the inclusion of alternative IT diffusion controls, economically as well as statistically.

Next consider Table 5. Column 1 confirms that lightning is strongly correlated with personal computer users; the R^2 is in fact slightly higher than what is true for Internet users. In general the results for personal computers are rather similar to those involving Internet diffusion. Nevertheless, there are two differences worth remarking on.

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[13] Details on all the data mentioned above are given in the Data Appendix.

First, it appears that the measure of human capital that holds the strongest explanatory power vis-à-vis computers is the fraction of the state population with a bachelor degree or above (BA), rather than the high school variable. The difference in R^2 in the two specifications is marginal though (cf. columns 4 and 5). To ease comparability we have therefore chosen to stick with the high school measure in the context of the robustness checks. But the results are very similar if we used the BA variable instead. Second, initial GSP per worker is not significant in the regressions. Nevertheless, on theoretical grounds we have chosen to keep it in the regressions to follow.

Examining columns 8-16 of Table 5 it is clear that lightning is robust to the inclusion of plausible alternative determinants of diffusion.[14] Again the point estimate for the flash density is very stable. Interestingly, comparing Table 4 and 5, one may observe that the size of the coefficient assigned to the flash density is numerically very similar in the two separate specifications. This could be taken to suggest that it is the same basic mechanism that affects both computer and Internet diffusion, in keeping with the theory developed above.

The lightning-IT correlation can obviously not be ascribed to reverse causality. Moreover, since the remaining diffusion determinants are lagged, the risk that endogeneity of these variables are contaminating the OLS estimate for lightning is diminished.

It is impossible to completely rule out that the partial correlation between lightning and IT could be attributed to one or more omitted variables in the analysis above. Still, a causal interpretation is well founded on theoretical grounds, and the empirical link between IT and lightning is clearly robust to a reasonable set of alternative IT determinants. Moreover, the point estimate seems stable across specifications. It falls in a reasonably confined interval between 0.01 and 0.02, no matter which determinant we include on top of human capital and labor productivity. These characteristics provide a reasonable basis for believing the estimates above can be taken to imply that lightning is causally impacting on the speed of IT diffusion.

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[14] We do not have data on exports sufficiently far back in time so as to allow it to enter in Table 5. This accounts for the fact that Table 5 is one column smaller than Table 4.

Accordingly, if we take the parameter estimate for lightning seriously, what is the economic strength of the link? Using the estimate from column 4 in Table 4 we find that a one standard deviation increase in lightning leads to a reduction in Internet users by about 1 percent.[15] In 2003 the states with the lowest Internet penetration (the 5th percentile) had about 44% of the population being able to access the Internet; at the other end of the spectrum (the 95th percentile) about 60% of the population was online. Hence the estimate for lighting implies that a one standard deviation change in lightning can account for about 7% of the 95/5 gap; four standard deviations therefore motivates about 25% of the difference.

The final issue is whether IT can account for the link between growth and lightning. Table 6 shows the relevant regression results. We focus specifically on the 1991-2007 period, as this is the period during which lightning is significantly correlated with growth.

>Table 6 about here<

In column 1 of Table 6 the lightning-growth correlation is reproduced. In the following two columns we add the two IT measures. Individually, both are significantly and positively correlated with growth as expected. The interpretation of the two right hand side variables is slightly different though. As noted above, the Internet originated in 1991. As a result, the independent variable can be seen as proxy for Internet investments over the period; in 1991 the number of Internet users inevitably was close to zero, so the 2003 value effectively captures *changes* in Internet users over the relevant period. Needless to say the same is not true for PCs, which started diffusing far earlier. If the IT investment rate is the relevant control, the PC variable is therefore measured with error. This may account for the fact that the economic size of the impact of the Internet variable is larger than that of PCs in Table 6.

The key result of the exercise, however, is reported in columns 4-6. When the IT variables are added to the equation, the flash density looses significance. The loss of significance is mainly attributably to a lower point estimate, which essentially is cut in half. A reasonable

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[15] Recall, the standard deviation of the flash density variable is 2.4 in our 48 state sample.

interpretation is that lightning appears in the growth regression due to its impact on IT diffusion. Column 6 introduces all three variables at once. Despite the obvious multicollinearity in this experiment (which explains the somewhat wobbly behavior of the Internet slope estimates), Internet remains significant: this means that the Internet dominates lightning (and computers) as a predictor of cross state growth rates in the Internet era: 1991 onwards.

We believe the above analysis builds a rather strong case in favour of the IT diffusion hypothesis; that is, the thesis that lightning appears as a growth determinant in the 1990s due to the growing influence of digital technologies on economic growth.

3.2 Climate Shocks

While the IT diffusion hypothesis is a viable explanation for the lightning-growth correlation, it is not *a priori* the only plausible one. Perhaps other climate related variables exert an impact on growth, and at the same time happen to be correlated with the flash density.

To begin with, lightning correlates with various kinds of weather phenomena that arise in the context of thunderstorms. Aside from lightning, thunderstorms produce four weather phenomena: tornadoes, high winds, heavy rainfall, and hailstorms. It seems plausible that these climate variables can induce changes in the growth rate in individual states in their own right. Each of them destroy property (physical capital), people (human capital), or both (Kunkel et al., 1999). By directly affecting the capital-labor ratio, the consequence of, say, a tornado could be changes in growth attributable to transitional dynamics. The nature of the transitional dynamics (i.e., whether growth rises or falls) is unclear, as it may depend on whether the tornado destroys more physical or human capital (e.g., Barro and Sala-i-Martin, 1995, Ch.5). [16] Nevertheless, since the lightning-growth correlation pertains to a relatively short time span (so far), it is hard to rule out that the above reasoning could account for it.

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[16] In a US context one may suspect a relatively larger impact on physical capital compared to human capital; if so climate shocks would tend to instigate a growth acceleration in their aftermath, as a higher marginal product of capital induces firms to invest in physical capital.

In addition, lightning correlates with temperature; hotter environments usually feature a higher flash density. Temperature has been documented to correlate with economic activity within countries (e.g., Nordhaus, 2006; Dell et al., 2009); therefore, we cannot rule out *a priori* that the link between lightning and growth is attributable to the intervening influence of temperature.[17]

Hence, in an effort to examine whether climate shocks could account for the lightning-growth correlation, we gathered data on all of the above weather phenomena: temperature, precipitation, tornadoes, hail size, and wind speed. In addition, we obtained data on topography (i.e., elevation) and latitude. The latter is a useful catch-all measure of climate. For good measure, we also obtained data on sunshine, humidity, and cloud cover (albeit it is not entirely clear why these weather phenomena should matter to growth). In total, we have data on ten alternative climate/geography variables; the details on the data are found in the Data Appendix.

With these data in hand, we ask two questions. First, ignoring lightning, do any of these weather phenomena exhibit a correlation with growth which is similar to that of lightning? That is, do any of them appear to become more strongly correlated with growth during the period 1977-2007? Second, taking lightning into account, do any of the above mentioned variables render lightning insignificant?

Tables 7 and 8 report the answer. As the lightning correlation does not depend appreciably on whether we invoke 5, 10 or 15 year epoch length we have chosen to focus on 10 year epochs. Results for 5 and 15 year epochs are similar, and available upon request.

>Tables 7 and 8 about here<

Columns 2-11 of Table 7 examine the potentially time varying impact from each weather variable; column 1 reproduces the lightning regularity from Section 2.2. It is plain to see that

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[17] Nordhaus (2006) and Dell et al. (2009) document a correlation between temperature and income *levels,* not growth. In fact, Dell et al. (2008) find that temperature is *not* correlated with growth in rich places, using cross-country data. Nevertheless, the link seems worth exploring.

none of the weather variables exhibit a similar growth correlation as that involving lightning. In fact, it is always the case that the variable in question is either insignificant, or tends to become less correlated with growth over time.

In Columns 2-11 of Table 8 we simultaneously include lightning and the various alternative climate/geography controls. In all cases, lightning remains significantly correlated with growth. In fact, when comparing the point estimate for lightning with or without (column 1) additional controls, it emerges that the point estimate is virtually unaffected.

In sum, these results suggest that the lightning-growth correlation is unlikely to be attributable to other weather phenomena.

3.3 Institutions and Integration

An extensive literature examines the impact from historical factors on long-run development. For instance, variation in colonial strategies seems to have an important impact on institutional developments around the world, thus affecting comparative economic development (e.g., Acemoglu et al., 2001). Similarly, initial relative factor endowments, determined in large part by climate and soil quality, may well have affected long-run development through inequality and human capital promoting institutions (Engermann and Sokoloff, 2000; Galor et al., 2008). Thus, in many instances the initial conditions that may have affected long-run developments are related to climate or geography. In the present context, therefore, it seems possible that the lightning-growth correlation may be picking up the influence from such long-run historical determinants of prosperity. Naturally, the conventional understanding would be that "deep determinants of productivity", e.g. determinants of political and economic institutions, should have a fairly time invariant impact on growth. As a result, it would not be surprising if such determinants do not exert a time varying impact on growth. But whether it is the case or not is obviously an empirical matter.

To examine whether the lightning-growth nexus is attributable to such effects, we obtained data on ten potential determinants of long-run performance for the US. The source of the data is Michener and McLean (2004), who examine the determinants of long-run productivity levels across US states. In addition, we collected state-level data on three dimensions of global integration, related to international movements of goods and capital. This leaves us with 13 different potential determinants of labor productivity growth, broadly capturing "institutions, geography and integration" (Rodrik et al., 2004).[18]

As in Section 3.2 we ask whether these determinants, individually, exhibit a time varying impact on growth, and whether their inclusion in the growth regression renders lightning insignificant.

>Table 9 and 10 about here<

In Table 9 we examine the impact from various historical determinants of productivity one-by-one. Interestingly, in several cases the impact does seem to vary across decades. Of particular note is column 11, which involves soldier mortality rates. Much like lightning the partial correlation seems stronger at the end of the period, compared to the beginning of the 1977-2007 period.

Table 10 includes both lightning and the individual controls. Since the soldier mortality rates is the only variable we have found so far that exhibits a correlation with growth that is qualitatively similar to that of lightning, the results reported in column 11 is of central importance. When both variables enter the growth regression only lightning retains explanatory power. The point estimate for the last period does decline a bit, and the statistical significance of lightning is somewhat reduced. But soldier mortality rates do not statistically dominate lightning in the specification. More broadly, it is once again worth observing how stable the partial correlation between lightning and growth seems to be. Comparing the results reported in column 1 (no historical controls) for lightning to those reported in columns 2-11 it is clear that the coefficient for lightning is quite robust.

>Table 11 about here<

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[18] See the Data Appendix for details.

Finally, Table 11 examines the potential influence from integration. Of particular note is column 3, from which it is clear that the influence from exports seems to have increased over the period. This result may have a reasonable interpretation. The EU common market (established in the early 1990s), and, perhaps more importantly, the emergence of China and India in world markets may well have left an imprint on growth. A likely path of influence would be trade. This can explain an intensification of the impact from trade in the 1990s, on labor productivity growth, through greater division of labor. While it thus seems that exports have become more important to growth at the end of the 1977-2007 period, column 6 reveals that trade does not account for the lightning-growth correlation that we documented in Section 2.

4. Concluding Remarks

In theory, lightning should impact on IT diffusion. Higher lightning intensity leads to more frequent power disruptions, which in turn reduces the longevity of IT equipment. As a result, by inducing higher IT user cost, a higher lighting frequency should hamper IT investments. By implications, high-tech societies may actually be quite vulnerable to climate shocks. Consistent with the temperate drift hypothesis, technological change may therefore render societies more sensitive to climate phenomena that previously were only of second order importance.

Empirically, we document that lightning activity is negatively correlated with measures of IT diffusion; computers and Internet hook-ups per household. Conditional on standard controls, states with less lightning have adopted IT more rapidly than states where lightning activity is more intensive.

Consistent with a detrimental impact on IT diffusion, we find that states with more lightning have grown slower from about 1990 onwards. This pattern cannot be accounted for by other climate phenomena, nor can it be explained by a time varying influence from deep historical determinants of productivity.

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Data Appendix

Lightning. Our main measure of lightning density, based on ground-based flash sensors, is from the U.S. National Lightning Detection Network Database (NLDN). The NLDN consists of more than 100 remote, ground-based lightning sensors, which instantly detect the electromagnetic signals appearing when lightning strikes Earth's surface. The data is available as an average over the period 1996-2005 for the 48 contiguous U.S. states from Vaisala's website: http://www.vaisala.com.

We find that lightning is not statistically different from a constant plus white noise (see main text for analysis). Therefore, we extend Vaisala's data to the period 1977-2007.

To investigate the time-series properties of lightning, we use data on the number of *thunder days* (TD) per year by state, available for the period 1901-1995. These data are collected as part of the Climate Change Detection and Attribution Program at the National Oceanic and Atmospheric Administration (NOAA). The raw data comes from 734 cooperative observer stations and 121 first order stations (see Changnon, 2001 for a detailed description). The data consists of monthly and yearly TD totals for 38 US states over the period 1901-1995, 40 states over the period 1906-1995 and 42 states over the period 1951-1995. It is available for purchase from the Midwestern Regional Climate Center:
http://mrcc.isws.illinois.edu/prod_serv/tstorm_cd/tstorm1.html.

From these data, we calculated the average yearly number of thunder days per state. Ultimately, we are interested in average *flash density* (FD) by state rather than thunder days per year. FDs are defined as the number of ground strikes per sq km per year. We converted yearly TDs into FDs using the following formula (Chisholm, 2000):

$$FD = 0.04 * TD^{1.25}$$

Temperature and Precipitation. Data from the United States Historical Climatology Network (USHCN) project, developed at NOAA's National Climatic Data Center (NCDC) to assist in the detection of regional climate change across the US. The USHCN project has produced a dataset of daily and monthly records of basic meteorological variables (maximum and minimum temperature, total precipitation, snowfall, and snow depth) from over 1000 stations across the 48 contiguous US states for the period 1900-2006.

The precipitation data we use is corrected by USHCN for the presence of outlier daily observations, time of data recording, and time series discontinuities due to random station moves and other station changes. The temperature data we use is additionally corrected for warming biases created by urbanization, and the replacement of liquid-in-glass thermometers by electronic temperature measurement devices during the mid 1980's.

We construct yearly average temperatures (expressed in degrees Celsius) and yearly average precipitation totals (expressed in cm per year) for each state, as simple averages of monthly data from 1221 stations across the country. The data is available at:
http://cdiac.ornl.gov/epubs/ndp/ushcn/newushcn.html.

Latitude. Latitude at the center of the state, calculated from geographic coordinates from the U.S. Board on Geographic Names. The data is available at: http://geonames.usgs.gov/domestic/download_data.htm.

Altitude. Approximate mean elevation by state. Data source: U.S. Geological Survey, Elevations and Distances in the United States, 1983. Available from the U.S. Census Bureau at: http://www.census.gov/prod/2004pubs/04statab/geo.pdf.

Tornadoes, Wind and Hail. The Storm Prediction Center of NOAA's National Weather Service Center provides data for tornadoes, wind and hail for the period 1950-2007.

Data is available for the tornado occurrences and their damage categories in the Enhanced Fujita (EF) scale (assigning 6 levels from 0 to 5). We construct a measure of tornado intensity as the average damage category for all tornado occurrences during a year. For all the estimations, we rescale the EF categories from the original 0 to 5 scale to a 1 to 6 scale.

Wind is measured as the yearly average of wind speed, expressed in kilometers per hour.

Hail is measured as the average size of hail in centimeters.

The data is available at http://www.spc.noaa.gov/climo/historical.html.

Humidity, Sunshine and Cloudiness. Data from the "Comparative Climatic Data for the United States through 2007", published by NOAA.

(Relative) humidity is the average percentage amount of moisture in the air, compared to the maximum amount of moisture that the air can hold at the same temperature and pressure.

Cloudiness is measured as the average number of days per year with 8/10 to 10/10 average sky cover (or with 7/8 to 8/8 average sky cover since July 1996).

Sunshine is the total time that sunshine reaches the Earth's surface compared to the maximum amount of possible sunshine from sunrise to sunset with clear sky conditions.

The data is available at http://www1.ncdc.noaa.gov/pub/data/ccd-data/CCD-2007.pdf.

GSP per worker. Gross Domestic Product by state (GSP) per worker in chained 2000 US$.

US Bureau of Economic Analysis (BEA) offers two series of real GSP. The first is for the period 1977-1997, where industry classification is based on the Standard Industrial Classification (SIC) definitions. The second series covers the period 1997-2007 and relies on industrial classification based on the North American industrial Classification System (NAICS). Both GSP series are available at http://www.bea.gov/regional/gsp/.

We build a single measure of real GSP, extending levels of the series based on the SIC system with the yearly growth rates of the series based on the NAICS. This is equivalent to assuming that from 1997 on, the growth rate of GSP per worker calculated with the SIC system equals the growth rate of real GSP calculated with the NAICS definitions.[19] Based on this estimate for real GSP, we construct a yearly series of real GSP per employed worker dividing real GSP by the number of employees per state. State-by-state data for the number of employed workers is provided by the State Personal Income accounts at the U.S. BEA (available at: http://www.bea.gov/regional/spi).

Computers and Internet. Percentage of households with computer and percentage of households with Internet access in 2003. Data collected in a supplement to the October 2003 U.S. Current Population Survey (CPS), available at: http://www.census.gov/population/socdemo/computer/2003/tab01B.xls.

Additional variables used in the paper

Variable	**Definition and source**
Human capital variables	This extended list of human capital variables is downloaded from www.allcountries.org.
Enrollment rate	Public elementary and secondary school enrollment as a percentage of persons 5-17 years old. From "Digest of Education Statistics", National Center of Education Statistics (NCES), Institute of Education Sciences, U.S. Department of Education, http://nces.ed.gov/programs/digest/. Available at: http://www.allcountries.org/uscensus/266_public_elementary_and_secondary_school_enrollment.html.
High school degree or higher	Persons with a high school degree or higher as a percentage of persons 25 years and over. From "Digest of Education Statistics", National Center of Education Statistics (NCES), Institute of Education Sciences, U.S. Department of Education, http://nces.ed.gov/programs/digest/d03/tables/dt011.asp.
Bachelor's degree or higher	Persons with a bachelor's degree or higher as a percentage of persons 25 years and over. Same source as high school degree or higher.
College degree or higher	Persons with a bachelor's degree or higher as a percentage of persons 25 years and over. Same source as high school degree or higher and bachelor's degree or higher.
Graduate or professional degree	Persons with a graduate or professional degree as a percentage of persons 25 years and over. Same source as high school degree or higher, bachelor's degree or higher, and college degree or higher.
Additional determinants of computer technology diffusion	In addition to human capital, Caselli and Coleman (2001) suggest the following set of determinants of computer technology diffusion across countries: real income, GDP shares of different sectors, stock of human capital, amount of trade, and degree of integration to the world economy. We gathered similar data for US states, described below.
Shares of Agriculture production, Manufacturing production, and Government Spending in GSP	Agriculture, forestry, fishing, and hunting production as % of GSP; Manufacturing production as % of GSP, Total Government spending as % of GSP. The 3 variables constructed from U.S. BEA's data of GSP by industry, in millions of current US$. Available at: http://www.bea.gov/regional/gsp/.

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[19] BEA warns against merging the *level* of the two series of real GSP directly, since the discontinuity in the industrial classification system will obviously affect level and growth rate estimates. Our choice of merging the *growth rates* of the two series can be justified recalling both the SIC and the NAICS aim to classify production of all industries in each state, so that the growth rate of both GSP series in levels is comparable. As a check, we computed the correlation between the growth rate of aggregate US GDP and gross domestic income (GDI), since GDP corresponds to the NAICS-definition and GDI corresponds to the SIC-definition (BEA, http://www.bea.gov/regional/gsp/). The correlation is higher than 0.99 for different periods between 1929 and 2007.

Agricultural exports per capita	Agricultural exports per capita (US$). Total value of Agricultural exports by state, from U.S. Department of Agriculture, divided by population. Available at: http://www.ers.usda.gov/Data/StateExports/2006/SXHS.xls Population data from U.S. Census Bureau.
Exports per capita	Exports per capita (US$). Total exports by state from U.S. Department of Commerce divided by population. Total exports data available for purchase from U.S. Census Bureau at http://www.census.gov/foreign-trade/reference/products/catalog/stateweb.html. Population data from the U.S. Census Bureau. Freely available for the period 1990-1999 at: http://allcountries.org/uscensus/1326_u_s_exports_by_state_of.html.
FDI per capita	Gross value of Property, Plant, and Equipment (PPE) of Nonbank U.S. Affiliates, per capita (US$). Data on PPE available from U.S. BEA for the period 1999-2006 available at: http://bea.doc.gov/international/xls/all_gross_ppe.xls. For the year 1981 and the period 1990-1997 available at: http://allcountries.org/uscensus/1314_foreign_direct_investment_in_the_u.html. Population data from U.S. Census Bureau.
Institutional and historical determinants of productivity	All variables are taken from Mitchener and McClean (2004). See the paper for detailed data sources.
% workforce in mining, 1880	Percentage of the workforce employed in mining in 1880.
Average no. cooling degree days	The average number of cooling degree days is computed as the number of days in which the average air temperature rose above 65 degrees Fahrenheit (18 degrees Celsius) times the number of degrees on those days which the average daily air temperature exceeded 65 over the year.
% of 1860 population in slavery	The total number of slaves as a percentage of the total population of each state in 1860.
% of 1860 population on large slave plantations	The number of slaves owned by slaveholders having more than 20 slaves as a percentage of the total population of each state in 1860.
Access to navigable water	An indicator variable that takes the value of one if a state borders the ocean/Great Lake /river, and zero otherwise.
Settler origin	A series of indicator variables which take on positive values if a state, prior to statehood, had ties with that colonial power.
Average annual soldier mortality in 1829-1838, 1839-1854, %	Soldier mortality rates at the state level are derived using U.S. soldier mortality data for individual forts. Quarterly data were collected by the US Surgeon General and Adjutant General's Offices 1829-1838 and by the US Surgeon General's Office for 1839-1854. Mitchener and McClean obtained the yearly mortality rates by dividing the number of deaths each year by the average annual "mean strength" of soldiers.

Figures

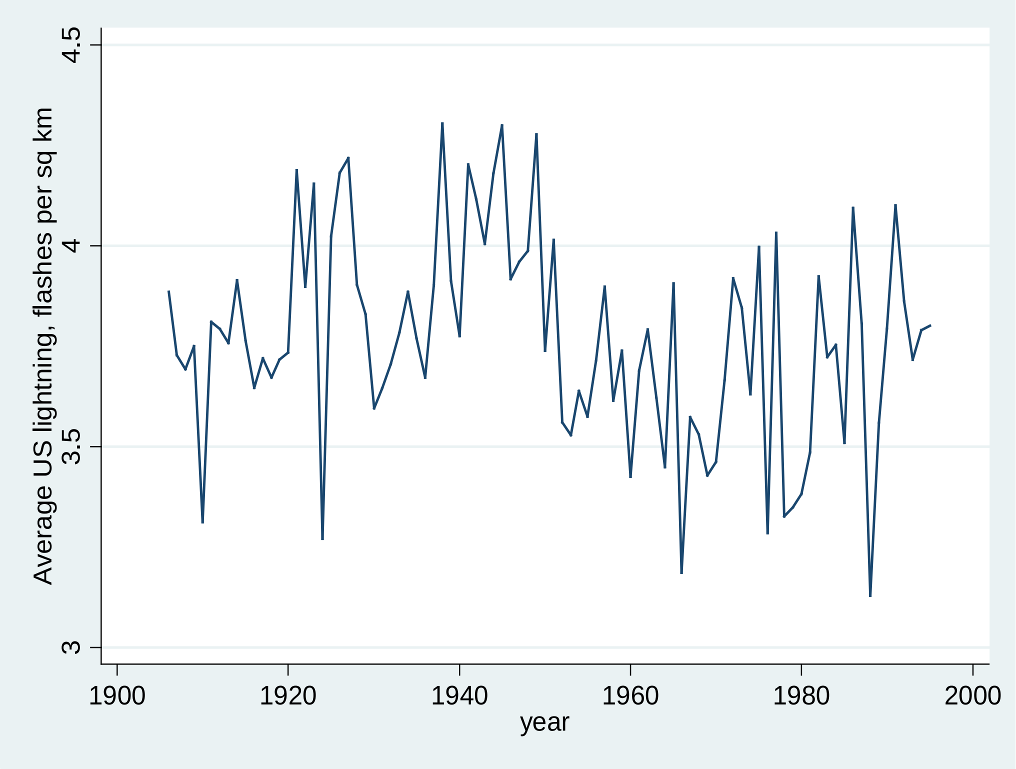


Figure 1. The average flash density in the US: 40 states

Source: Lightning observations from weather stations, transformed from thunder days (TD) into flash density (FD) using the formula FD = $0.04^{*}TD^{1.25}$. See Data Appendix for details.

Notes: Only 40 states have complete information for the period 1906-1995. The "left-out" (contiguous) states are: Connecticut, Delaware, New Hampshire, New Jersey, Rhode Island, Vermont, Mississippi, and West Virginia. The figure shows the weighted average, where the weight is determined by state size.

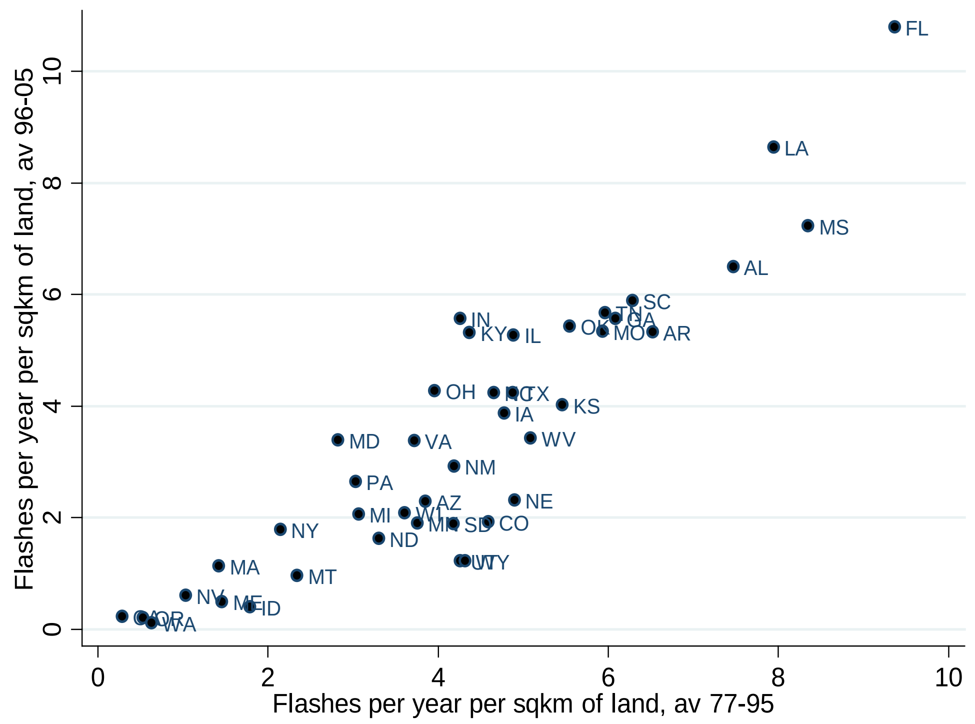


Figure 2. The average flash density 1977-95 versus 1996-2005: 42 states.

Sources: 1977-95 based on Thunder days (TD) from weather station observations, converted into flash density (FD) using the formula $FD = 0.04*TD^{1.25}$. 1996-2005 data are based on ground detectors. See Appendix for further details.

Notes: The correlation is 0.90, and a regression, $FL_{96\text{-}05} = a + bFL_{77\text{-}95}$ returns: a=-0.99, b=1.05, R^2=0.81.

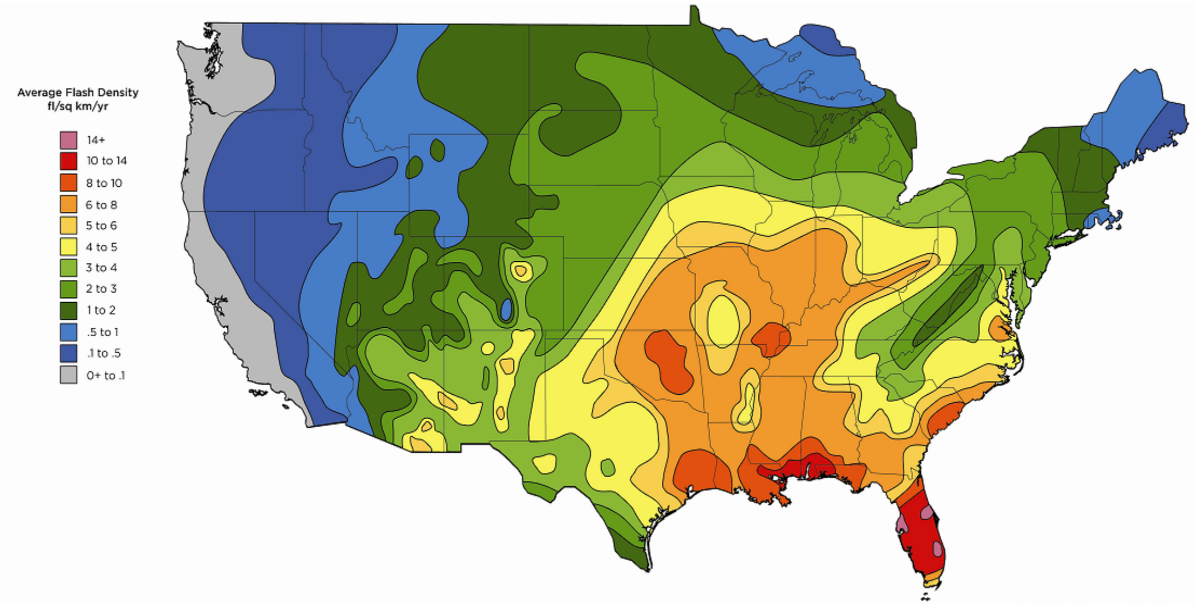
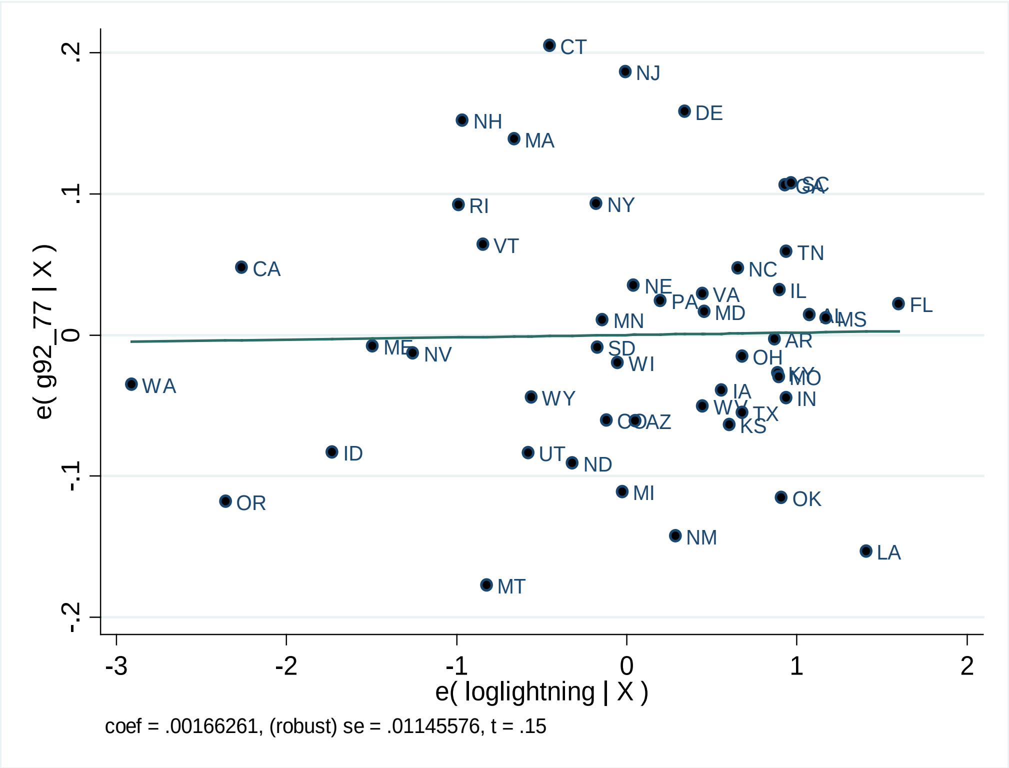


Figure 3. The distribution of flash densities across the US: 1996-2007.
Source: Vaisala.



coef = .00166261, (robust) se = .01145576, t = .15

Figure 4. The correlation between state growth and (log) flash density, conditional on a constant and initial income per worker: 1977-1992.

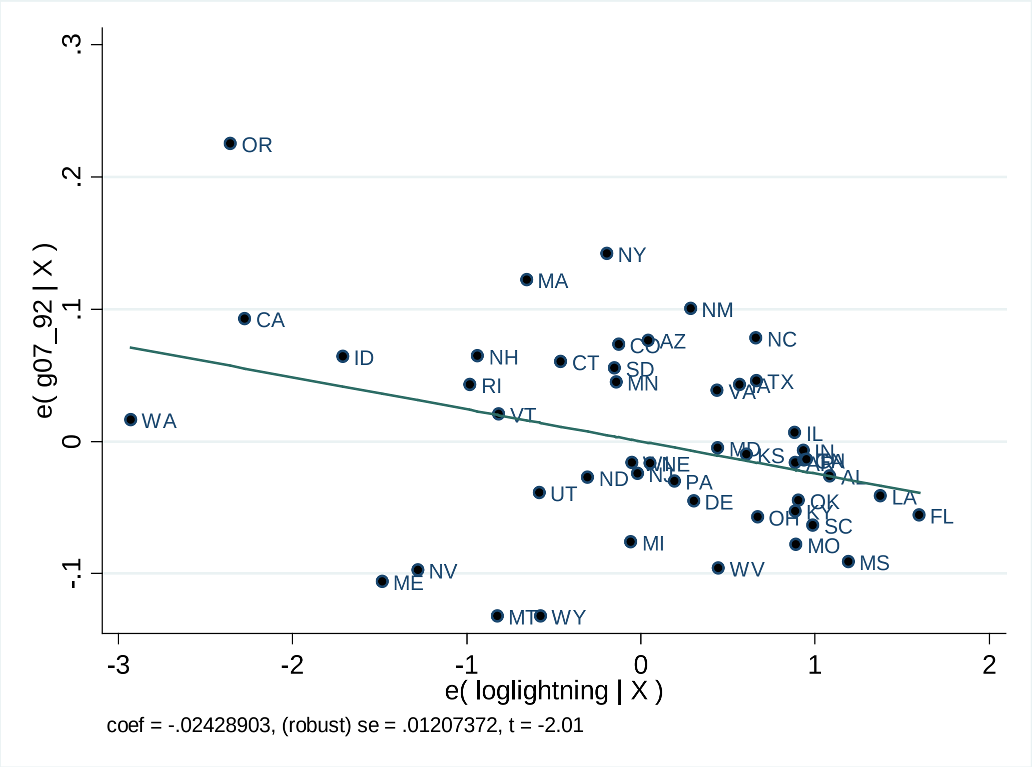


Figure 5. The correlation between state growth and (log) flash density, conditional on a constant and initial income per worker: 1992-2007.

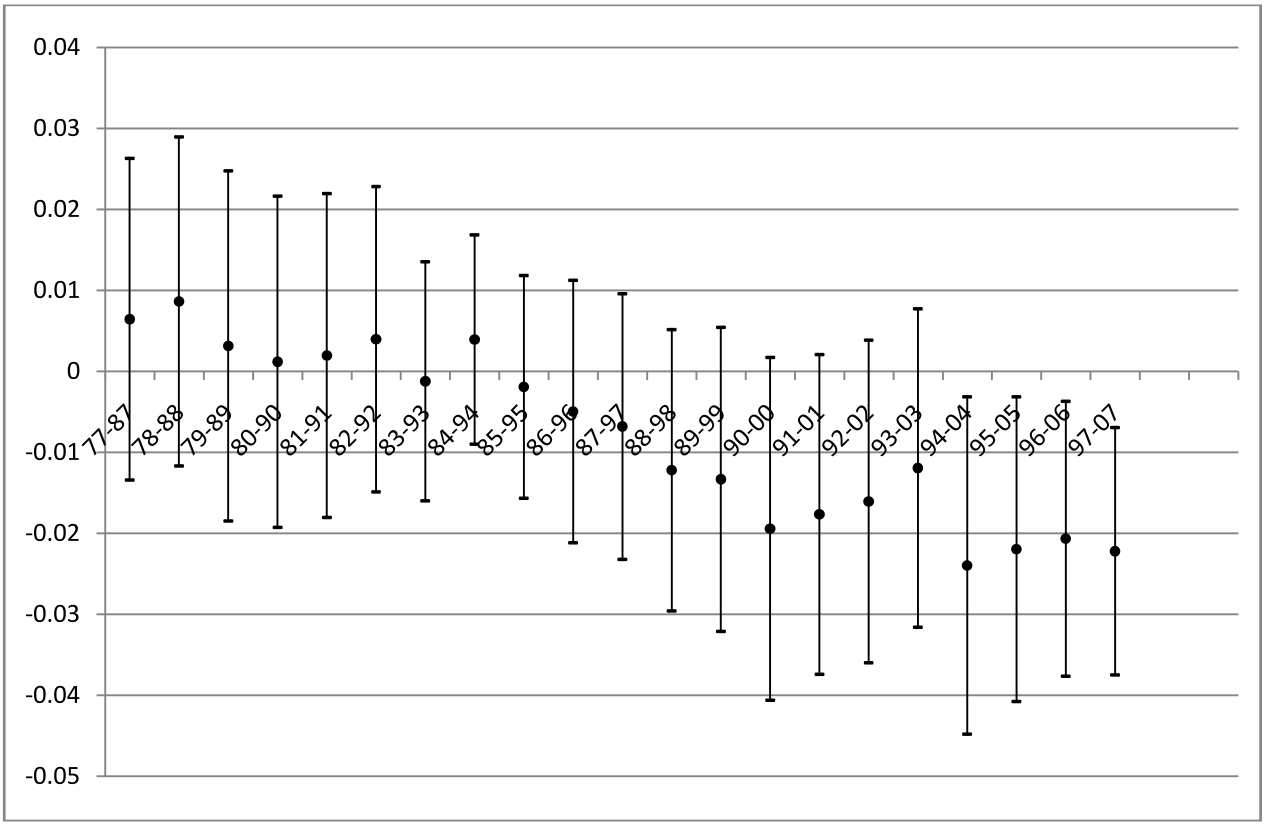


Figure 6. The lightning-growth nexus: 1977-2007.

Notes: The figure shows estimates for b_2 (and the associated 95% confidence interval) from regressions of the form: $\log(y_t)-\log(y_{t-10})= b_0 + b_1\log(y_{t-10})+ b_2\log(\text{lightning})+e$, where y is gross state product per worker, and t=1985,…,2007. 48 states; estimates by OLS.

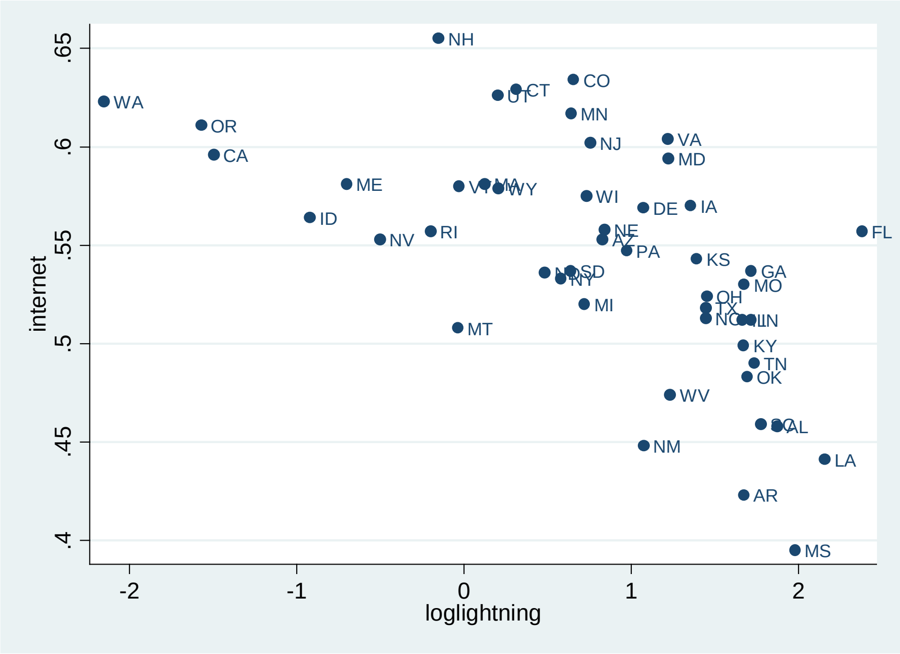


Figure 7. Lightning versus Internet users per 100 households in 2003.

Sources: See Data Appendix

Notes: The raw correlation between the two series is -0.62.

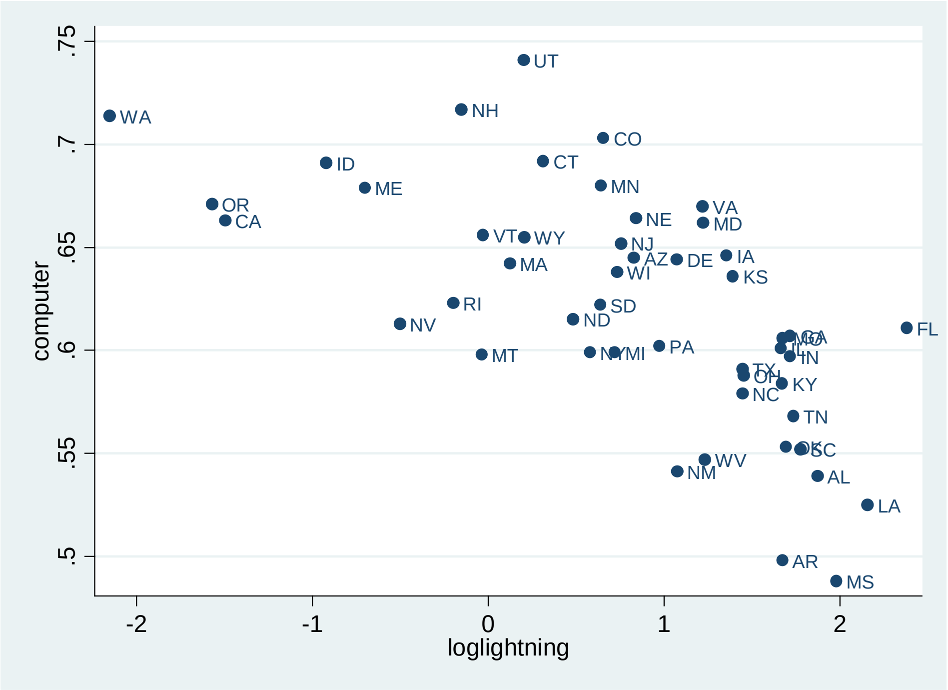


Figure 8. Lightning versus personal computers per 100 households in 2003.

Sources: See Data Appendix.

Notes: The raw correlation between the two series is -0.65.

Table 1. Dickey-Fuller tests for unit root in lightning

	test-statistic	p-value	No. obs.	No. lags
Aggregate US	-4.516	0.000	88	1
Alabama	-5.312	0.000	88	1
Arizona	-3.375	0.012	87	2
Arkansas	-8.980	0.000	89	0
California	-8.401	0.000	89	0
Colorado	-8.686	0.000	89	0
Florida	-8.187	0.000	89	0
Georgia	-8.576	0.000	89	0
Idaho	-3.480	0.009	87	2
Illinois	-9.606	0.000	89	0
Indiana	-8.241	0.000	89	0
Iowa	-9.416	0.000	89	0
Kansas	-4.460	0.000	88	1
Kentucky	-2.937	0.041	87	2
Louisiana	-4.622	0.000	88	1
Maine	-2.747	0.066	87	2
Maryland	-5.321	0.000	88	1
Massachusetts	-9.254	0.000	89	0
Michigan	-8.763	0.000	89	0
Minnesota	-10.283	0.000	89	0
Missouri	-9.918	0.000	89	0
Montana	-9.014	0.000	89	0
Nebraska	-3.636	0.005	87	2
Nevada	-10.020	0.000	89	0
New Mexico	-3.576	0.006	87	2
New York	-4.013	0.001	88	1
North Carolina	-5.404	0.000	88	1
North Dakota	-7.839	0.000	89	0
Ohio	-3.591	0.006	87	2
Oklahoma	-11.615	0.000	89	0
Oregon	-7.090	0.000	89	0
Pennsylvania	-2.205	0.204	86	3
South Carolina	-8.012	0.000	89	0
South Dakota	-8.624	0.000	89	0
Tennessee	-7.322	0.000	89	0
Texas	-5.448	0.000	88	1
Utah	-5.551	0.000	88	1
Virginia	-7.409	0.000	89	0
Washington	-8.751	0.000	89	0
Wisconsin	-9.453	0.000	89	0
Wyoming	-7.708	0.000	89	0

Notes. The Augmented Dickey-Fuller test with no deterministic trend for each of the 40 states over the period 1906-1995. Lags selected by Schwarz's information criteria. Lightning is average number of flashes per year per square km, measured at weather stations.

Table 2. Summary statistics for the main variables

				Percentiles				
	Obs.	**Mean**	**Std. Dev.**	**99%**	**75%**	**50%**	**25%**	**1%**
Lightning, average 1996-2005 (flashes/year/sq km)	48	3.18	2.39	10.79	5.30	2.48	1.23	0.12
Annual growth rate of real GSP per worker, average 1977-2007 (%)	48	1.07	0.42	1.97	1.37	1.07	0.82	0.10
Internet presence, 2003 (%)	48	54.4	5.9	65.5	58.1	55.0	51.2	39.5
Computer presence, 2003 (%)	48	62.1	5.7	74.1	66.3	61.9	59.0	48.8

Notes. Lightning defined as average number of flashes per year per square km over the period 1995-2006, measured by flash-detectors.

Table 3. Lightning and growth

(1)	5 year periods	**1978-1982**	**1983-1987**	**1988-1992**	**1993-1997**	**1998-2002**	**2003-2007**	Observations	R-squared
		-0.037	0.171	-0.093	-0.042	-0.280**	-0.175*	288	0.20
		[0.098]	[0.162]	[0.092]	[0.124]	[0.109]	[0.088]		

(2)	10 year periods	**1978-1987**	**1988-1997**	**1998-2007**	Observations	R-squared
		0.0675	-0.0656	-0.224***	144	0.15
		[0.103]	[0.0770]	[0.0765]		

(3)	15 year periods	**1978-1992**	**1993-2007**	Observations	R-squared
		0.0122	-0.162**	96	0.20
		[0.0777]	[0.0782]		

Notes. Pooled OLS estimates of the coefficient on lightning (b_{2t}). The dependent variable is the yearly growth rate of GSP per worker over periods of 5, 10, and 15 years, respectively. All regressions include a constant, the initial level of (log) real GSP per worker and a full set of time-dummies. Lightning is the (log) average number of flashes per year per square km, measured by flash-detectors. Robust standard errors in brackets, adjusted for clustering at state level. Asterisks ***, **, and * indicate significance at the 1, 5, and 10%, respectively.

Table 4. Lightning and Internet diffusion

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Lightning	-3.57***	-3.57***	-3.63***	-1.21***	-2.30***	-2.51***	-3.10***	-1.20***	-1.20***	-1.30**	-1.08**	-1.22***	-0.90*	-1.22***	-1.29***	-1.39***	-1.38***
	[0.61]	[0.62]	[0.63]	[0.44]	[0.46]	[0.52]	[0.53]	[0.44]	[0.44]	[0.49]	[0.50]	[0.42]	[0.48]	[0.44]	[0.43]	[0.51]	[0.45]
(log) Real GSP per worker, 1991		9.95***	8.95**	8.99***	1.66	3.09	3.07	6.31*	8.55**	9.13***	7.04**	11.58***	6.30*	8.89***	7.48***	8.02***	9.00***
		[3.46]	[3.61]	[2.85]	[3.30]	[3.08]	[4.43]	[3.58]	[3.58]	[2.88]	[2.63]	[3.36]	[3.26]	[2.99]	[2.51]	[2.78]	[2.84]
Enrollment rate, 1991			-11.54														
			[14.57]														
High school degree or higher, 1990				71.04***				73.91***	71.05***	74.82***	71.87***	68.46***	76.43***	72.51***	73.15***	73.22***	78.65***
				[9.86]				[10.14]	[9.97]	[9.84]	[9.93]	[10.82]	[10.98]	[11.11]	[10.20]	[10.26]	[13.60]
Bachelor's degree or higher, 1991					0.86***												
					[0.14]												
College degree or higher, 1998						66.96***											
						[10.12]											
Graduate or professional degree, 1990							125.56***										
							[45.86]										
Share of agriculture in GSP, 1991								-29.17									
								[21.05]									
Share of government in GSP, 1991									-4.82								
									[25.08]								
Share of manufacturing in GSP, 1991										10.2							
										[8.42]							
(log) Exports per capita, 1991											1.050						
											[1.09]						
(log) FDI per capita, 1991												-1.64					
												[1.05]					
(log) Agricultural exports per capita, 1991													-0.67*				
													[0.37]				
Soldier mortality, 1829-1854														12.36			
														[55.69]			
(log) Population, 1991															0.63		
															[0.40]		
% of workforce in mining, 1880																-6.63	
																[5.48]	
% of slavery, 1860																	4.26
																	[4.21]
Constant	57.18***	-49.77	-28.33	-95.32***	20.97	7.28	15.33	-67.95*	-89.88**	-101.40***	-82.24***	-108.72***	-67.62*	-95.62***	-90.08***	-86.05***	-101.52***
	[0.72]	[37.19]	[44.27]	[31.10]	[34.28]	[32.29]	[45.65]	[37.59]	[41.30]	[32.75]	[27.97]	[31.50]	[33.83]	[31.52]	[27.52]	[30.82]	[32.78]
Observations	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
R-squared	0.38	0.45	0.46	0.73	0.66	0.64	0.54	0.74	0.73	0.74	0.74	0.75	0.75	0.73	0.74	0.74	0.74

Notes. OLS estimates. The dependent variable is the percentage of households with access to the Internet in 2003. Lightning is the (log) average number of flashes per year per square km, measured by flash-detectors. The rest of the covariates are described in the Data Appendix. Robust standard errors in brackets. Asterisks ***, **, and * indicate significance at the 1, 5, and 10%, respectively.

Table 5. Lightning and computer diffusion

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Lightning	-3.68***	-3.67***	-3.56***	-1.40***	-2.13***	-2.74***	-3.26***	-1.23**	-1.37***	-1.22**	-1.41***	-0.98*	-1.32***	-1.46***	-1.53***	-1.48***
	[0.56]	[0.58]	[0.60]	[0.46]	[0.49]	[0.53]	[0.51]	[0.50]	[0.48]	[0.47]	[0.48]	[0.51]	[0.43]	[0.51]	[0.49]	[0.50]
(log) Real GSP per worker, 1977		2.4	2.81	-1.27	-2.82	-1.44	-1.39	-4.17	-0.48	-2.35	-0.77	-2.43	-0.43	-2.6	-1.78	-1.19
		[3.87]	[4.24]	[3.02]	[3.00]	[3.20]	[3.42]	[3.56]	[3.13]	[2.67]	[3.37]	[2.90]	[3.46]	[3.78]	[2.85]	[3.14]
Enrollment rate, 1980			7.35													
			[17.82]													
High school degree or higher, 1980				47.65***				51.62***	47.46***	56.43***	47.12***	51.51***	43.34***	49.54***	52.59***	51.64***
				[8.76]				[9.60]	[8.45]	[9.11]	[9.41]	[9.38]	[10.66]	[8.72]	[9.27]	[9.95]
Bachelor's degree or higher, 1977					4.47***											
					[0.73]											
College degree or higher, 1998						59.70***										
						[10.84]										
Graduate or professional degree, 1990							112.71***									
							[35.25]									
Share of agriculture in GSP, 1977								-23.27								
								[14.52]								
Share of government in GSP, 1977									21.38							
									[20.85]							
Share of manufacturing in GSP, 1977										14.17**						
										[6.72]						
(log) FDI per capita, 1981											-0.36					
											[0.70]					
(log) Agricultural exports per capita 1977												-0.57*				
												[0.29]				
Soldier mortality, 1829-1854													-53.62			
													[62.71]			
(log) Population, 1977														0.52		
														[0.58]		
% of workforce in mining, 1880															-9.61	
															[6.56]	
% of slavery, 1860																2.71
																[4.50]
Constant	64.97***	39.4	28.51	44.79	41.57	65.37*	71.79*	73.69**	33.44	47.24	42.17	56.56*	39.79	50.07	47.54	41.08
	[0.72]	[41.23]	[53.08]	[31.95]	[31.36]	[34.08]	[36.05]	[36.21]	[34.36]	[28.32]	[33.58]	[30.29]	[34.27]	[35.53]	[30.40]	[33.80]
Observations	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
R-squared	0.43	0.43	0.43	0.63	0.65	0.61	0.52	0.64	0.64	0.67	0.63	0.65	0.64	0.64	0.65	0.63

Notes. OLS estimates. The dependent variable is percentage of households with a personal computer at home in 2003. Lightning is the (log) average number of flashes per year per square km, measured by flash-detectors. The rest of the covariates are described in the Data Appendix. Robust standard errors in brackets. Asterisks ***, **, and * indicate significance at the 1, 5, and 10%, respectively.

Table 6. Growth, lightning, and IT

	(1)	(2)	(3)	(4)	(5)	(6)
(log) Real GSP per worker, 1991	-0.106	-0.131*	-0.159**	-0.121*	-0.147**	-0.191***
	[0.0652]	[0.0703]	[0.0713]	[0.0672]	[0.0687]	[0.0700]
Lightning	-0.0250**			-0.0149	-0.0102	-0.0149
	[0.0121]			[0.0164]	[0.0147]	[0.0147]
Computer presence, 2003		0.451**		0.275		-1.226
		[0.192]		[0.250]		[0.733]
Internet presence, 2003			0.531***		0.414*	1.545**
			[0.181]		[0.218]	[0.693]
Constant	1.371*	1.342*	1.630**	1.357*	1.577**	2.201***
	[0.703]	[0.723]	[0.731]	[0.712]	[0.710]	[0.767]
Observations	48	48	48	48	48	48
R-squared	0.15	0.15	0.19	0.17	0.20	0.24

Notes. OLS estimates. The dependent variable is the yearly growth rate of GSP per worker over the period 1991-2007. Computer access is the % of households with a computer at home, and Internet access is the % of households with access to Internet. Lightning is the (log) average number of flashes per year per square km, measured by flash-detectors. Robust standard errors in brackets. Asterisks ***, **, and * indicate significance at the 1, 5, and 10%, respectively.

Table 7. Growth regressions with geographical and climate controls

GEOGRAPHY: (log)	Lightning (flashes/year/ sqkm) (1)	Temperature (C degrees) (2)	Precipitation (cm/year) (3)	Tornado intensity (av EF-scale) (4)	Hail size (cm) (5)	Wind speed (km/h) (6)	Humidity (% moisture in air) (7)	Cloudiness (days/year) (8)	Sunshine (days/year) (9)	Elevation (meters above sea level) (10)	Latitude (degrees) (11)
(log) Real GSP per worker, initial	-0.717	-0.724	-0.837*	-0.823*	-0.896*	-0.66	-0.657	-0.67	-0.857	-0.829*	-0.702
	[0.452]	[0.455]	[0.440]	[0.441]	[0.457]	[0.466]	[0.450]	[0.440]	[0.523]	[0.460]	[0.449]
GEOGRAPHY × t_{78-87}	0.0675	0.0483	1.060***	1.833***	-0.565	-0.413***	2.141**	0.888	-1.324	-0.361***	-0.199
	[0.103]	[0.284]	[0.197]	[0.381]	[0.890]	[0.137]	[0.833]	[0.541]	[0.857]	[0.0830]	[0.913]
GEOGRAPHY × t_{88-97}	-0.0656	0.15	0.254	0.24	-0.542	0.00992	-0.953	-0.165	-0.283	-0.022	-0.0267
	[0.0770]	[0.253]	[0.256]	[0.437]	[0.717]	[0.0981]	[0.767]	[0.426]	[0.539]	[0.0910]	[0.834]
GEOGRAPHY × t_{98-07}	-0.224***	-0.124	0.0797	-0.236	-1.987	0.191	-0.97	-0.332	0.00247	0.0749	0.734
	[0.0765]	[0.225]	[0.179]	[0.316]	[1.215]	[0.428]	[0.699]	[0.414]	[0.697]	[0.0724]	[0.550]
Observations	144	144	144	144	144	144	144	144	141	144	144
R-squared	0.15	0.11	0.23	0.21	0.13	0.16	0.15	0.13	0.14	0.23	0.11

Notes. Pooled OLS estimates. The dependent variable is the yearly growth rate of GSP per worker over the periods 1978-1987, 1988-1997, and 1998-2007. All regressions include a constant and a full set of time-dummies. All geographic/climate variables are (log) annual averages taken over periods of 10 years, described in the Data Appendix. Lightning is the (log) average number of flashes per year per square km, measured by flash-detectors. Robust standard errors in brackets, adjusted for clustering at the state level. Asterisks ***, **, and * indicate significance at the 1, 5, and 10%, respectively.

Table 8. Growth regressions with geographical and climate controls, conditional on lightning

GEOGRAPHY: (log)		Temperature (C degrees)	Precipitation (cm/year)	Tornado intensity (av EF-scale)	Hail size (cm)	Wind speed (km/h)	Humidity (% moisture in air)	Cloudiness (days/year)	Sunshine (days/year)	Elevation (meters above sea level)	Latitude (degrees)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(log) Real GSP per worker, initial	-0.717	-0.801*	-0.921**	-0.863*	-0.837*	-0.676	-0.651	-0.668	-0.851	-1.041**	-0.746
	[0.452]	[0.471]	[0.426]	[0.433]	[0.477]	[0.463]	[0.455]	[0.445]	[0.522]	[0.470]	[0.463]
Lightning × $t_{78\text{-}87}$	0.0675	0.0793	-0.0661	-0.0637	0.123	-0.169	-0.00118	0.0991	0.105	-0.15	0.0909
	[0.103]	[0.113]	[0.141]	[0.116]	[0.120]	[0.137]	[0.135]	[0.117]	[0.114]	[0.116]	[0.129]
Lightning × $t_{88\text{-}97}$	-0.0656	-0.13	-0.114	-0.102	-0.056	-0.0749	-0.0394	-0.0731	-0.0629	-0.104	-0.122
	[0.0770]	[0.0831]	[0.0876]	[0.0957]	[0.0811]	[0.0868]	[0.0851]	[0.0766]	[0.0736]	[0.0977]	[0.0913]
Lightning × $t_{98\text{-}07}$	-0.224***	-0.293***	-0.253***	-0.222***	-0.210**	-0.233***	-0.214**	-0.240***	-0.234***	-0.245**	-0.294***
	[0.0765]	[0.0885]	[0.0819]	[0.0805]	[0.0890]	[0.0798]	[0.0833]	[0.0760]	[0.0820]	[0.0945]	[0.101]
GEOGRAPHY × $t_{78\text{-}87}$		-0.0594	1.120***	1.946***	-0.95	-0.579***	2.146**	0.967*	-1.470*	-0.430***	0.288
		[0.314]	[0.263]	[0.450]	[0.983]	[0.181]	[1.030]	[0.549]	[0.840]	[0.0877]	[1.120]
GEOGRAPHY × $t_{88\text{-}97}$		0.333	0.358	0.441	-0.445	-0.0303	-0.827	-0.224	-0.195	-0.0784	-0.691
		[0.263]	[0.274]	[0.524]	[0.767]	[0.110]	[0.831]	[0.420]	[0.506]	[0.108]	[0.997]
GEOGRAPHY × $t_{98\text{-}07}$		0.366	0.25	-0.0403	-0.4	-0.163	-0.279	-0.524	0.329	-0.0401	-0.859
		[0.268]	[0.203]	[0.281]	[1.222]	[0.419]	[0.859]	[0.341]	[0.600]	[0.0829]	[0.711]
Observations	144	144	144	144	144	144	144	144	141	144	144
R-squared	0.15	0.17	0.29	0.26	0.16	0.22	0.19	0.19	0.19	0.29	0.16

Notes. Pooled OLS estimates. The dependent variable is the yearly growth rate of GSP per worker over the periods 1978-1987, 1988-1997, and 1998-2007. All regressions include a constant and a full set of time-dummies. All geographic/climate variables are (log) annual averages taken over periods of 10 years. Lightning is the (log) average number of flashes per year per square km, measured by flash-detectors. Robust standard errors in brackets, adjusted for clustering at state level. Asterisks ***, **, and * indicate significance at the 1, 5, and 10%, respectively.

Table 9. Growth regressions with historical controls (geography and institutions)

HISTORY:		% of workforce in mining, 1880	Average no. of cooling degree days	% of 1860 population in slavery	Access to navigable water	% of 1860 population on large slave plantations	Settler origin: English	Settler origin: French	Settler origin: Spanish	Settler origin: Dutch	Average annual soldier mortality in 1829-1838, 1839-1854, %
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(log) Real GSP per worker, initial	-0.717	-0.712	-0.729	-0.677	-0.873*	-0.681	-0.720*	-1.234***	-0.726*	-1.026**	-0.668
	[0.452]	[0.441]	[0.447]	[0.452]	[0.448]	[0.453]	[0.429]	[0.428]	[0.401]	[0.431]	[0.450]
Lightning × t_{78-87}	0.0675										
	[0.103]										
Lightning × t_{88-97}	-0.0656										
	[0.0770]										
Lightning × t_{98-07}	-0.224***										
	[0.0765]										
HISTORY × t_{78-87}		-2.948***	-0.0035	1.096**	0.742***	1.796*	0.704***	-0.427**	-0.686***	0.655***	-1.901
		[0.676]	[0.0121]	[0.544]	[0.204]	[0.909]	[0.185]	[0.208]	[0.191]	[0.202]	[10.49]
HISTORY × t_{88-97}		-0.671	-0.00742	-0.606	0.294	-1.211*	0.117	-0.554***	-0.261	0.450*	-5.361
		[0.926]	[0.0102]	[0.429]	[0.255]	[0.684]	[0.186]	[0.159]	[0.165]	[0.228]	[8.782]
HISTORY × t_{98-07}		0.843	-0.00491	-0.691*	0.0492	-1.139**	-0.0453	-0.358**	0.0247	0.362	-15.99**
		[0.714]	[0.00996]	[0.364]	[0.180]	[0.529]	[0.178]	[0.168]	[0.163]	[0.294]	[6.836]
Observations	144	144	144	144	144	144	144	144	144	144	144
R-squared	0.15	0.18	0.11	0.15	0.19	0.16	0.20	0.21	0.21	0.15	0.13

Notes. Pooled OLS estimates. The dependent variable is the yearly growth rate of GSP per worker over the periods 1978-1987, 1988-1997, and 1998-2007. All regressions include a constant and a full set of time-dummies. Lightning is the (log) average number of flashes per year per square km, measured by flash-detectors. All HISTORY variables taken from Mitchener and McLean (2004). Robust standard errors in brackets, adjusted for clustering at state level. Asterisks ***, **, and * indicate significance at the 1, 5, and 10%, respectively.

Table 10. Growth regressions with historical controls (geography and institutions) and lightning

HISTORY:		% of workforce in mining, 1880	Average no. of cooling degree days	% of 1860 population in slavery	Access to navigable water	% of 1860 population on large slave plantations	Settler origin: English	Settler origin: French	Settler origin: Spanish	Settler origin: Dutch	Average annual soldier mortality in 1829-1838, 1839-1854, %
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(log) Real GSP per worker, initial	-0.717	-0.784*	-0.700	-0.655	-0.964**	-0.66	-0.726	-1.199***	-0.741*	-1.020**	-0.674
	[0.452]	[0.433]	[0.455]	[0.465]	[0.444]	[0.465]	[0.435]	[0.439]	[0.402]	[0.436]	[0.459]
Lightning × t_{78-87}	0.0675	-0.0554	0.142	-0.0649	-0.0262	-0.0502	0.0596	0.116	0.0407	0.0743	0.108
	[0.103]	[0.130]	[0.110]	[0.130]	[0.128]	[0.125]	[0.104]	[0.0964]	[0.0951]	[0.101]	[0.114]
Lightning × t_{88-97}	-0.0656	-0.11	-0.0444	-0.00698	-0.112	0.00519	-0.0669	-0.0062	-0.0763	-0.0593	-0.0519
	[0.0770]	[0.0883]	[0.0741]	[0.0876]	[0.0886]	[0.0843]	[0.0797]	[0.0904]	[0.0777]	[0.0757]	[0.0752]
Lightning × t_{98-07}	-0.224***	-0.229**	-0.327***	-0.230**	-0.255***	-0.222**	-0.223***	-0.197**	-0.224***	-0.221***	-0.192*
	[0.0765]	[0.0896]	[0.0847]	[0.0923]	[0.0837]	[0.0910]	[0.0760]	[0.0891]	[0.0771]	[0.0787]	[0.0994]
HISTORY × t_{78-87}		-3.183***	-0.0141	1.312**	0.765***	2.051**	0.701***	-0.473**	-0.679***	0.663***	-7.631
		[0.871]	[0.0114]	[0.627]	[0.243]	[1.018]	[0.187]	[0.214]	[0.195]	[0.206]	[11.70]
HISTORY × t_{88-97}		-1.157	-0.00406	-0.583	0.387	-1.237	0.121	-0.548***	-0.274	0.442*	-2.601
		[1.063]	[0.0102]	[0.497]	[0.288]	[0.777]	[0.187]	[0.178]	[0.168]	[0.236]	[9.035]
HISTORY × t_{98-07}		-0.149	0.0197***	0.0697	0.25	-0.0257	-0.0342	-0.269	-0.012	0.334	-5.793
		[0.968]	[0.00656]	[0.443]	[0.216]	[0.676]	[0.158]	[0.176]	[0.147]	[0.283]	[8.423]
Observations	144	144	144	144	144	144	144	144	144	144	144
R-squared	0.15	0.22	0.17	0.18	0.24	0.19	0.24	0.25	0.25	0.20	0.16

Notes. Pooled OLS estimates. The dependent variable is the yearly growth rate of GSP per worker over the periods 1978-1987, 1988-1997, and 1998-2007. All regressions include a constant and a full set of time-dummies. Lightning is the (log) average number of flashes per year per square km, measured by flash-detectors. All HISTORY variables taken from Mitchener and McLean (2004). Robust standard errors in brackets, adjusted for clustering at state level. Asterisks ***, **, and * indicate significance at the 1, 5, and 10%, respectively.

Table 11. Growth regressions with trade/integration controls and lightning

INTEGRATION: (log)		Agricultural exports per capita	Exports per capita	FDI per capita	Agricultural exports per capita	Exports per capita	FDI per capita
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(log, initial) Real GDP per worker	-0.717	-1.017**	-1.124**	-0.41	-0.994**	-1.103**	-0.417
	[0.452]	[0.443]	[0.432]	[0.546]	[0.444]	[0.438]	[0.559]
Lightning × $t_{78\text{-}87}$	0.0675				0.149*	0.0949	0.074
	[0.103]				[0.0871]	[0.113]	[0.107]
Lightning × $t_{88\text{-}97}$	-0.0656				-0.0397	-0.0487	-0.0621
	[0.0770]				[0.0792]	[0.0870]	[0.0790]
Lightning × $t_{98\text{-}07}$	-0.224***				-0.226***	-0.197**	-0.223***
	[0.0765]				[0.0776]	[0.0744]	[0.0748]
INTEGRATION × $t_{78\text{-}87}$		-0.183***	0.252	-0.123	-0.201***	0.275	-0.13
		[0.0476]	[0.203]	[0.163]	[0.0496]	[0.198]	[0.158]
INTEGRATION × $t_{88\text{-}97}$		-0.143**	0.2	-0.127	-0.138**	0.184	-0.114
		[0.0584]	[0.218]	[0.184]	[0.0601]	[0.233]	[0.189]
INTEGRATION × $t_{98\text{-}07}$		-0.01	0.368***	-0.421***	0.0094	0.308**	-0.420***
		[0.0515]	[0.123]	[0.122]	[0.0493]	[0.126]	[0.130]
Observations	144	144	144	144	144	144	144
R-squared	0.15	0.218	0.155	0.133	0.275	0.194	0.179

Notes. Pooled OLS estimates. The dependent variable is the yearly growth rate of GSP per worker over the periods 1978-1987, 1988-1997, and 1998-2007. All regressions include a constant and a full set of time-dummies. Lightning is the (log) average number of flashes per year per square km, measured by flash-detectors. Robust standard errors in brackets, adjusted for clustering at state level. Asterisks ***, **, and * indicate significance at the 1, 5, and 10%, respectively.

Table A1. Tests for whether lightning is a constant plus white noise

	Breusch-Godfrey test			Runs test	
	test-statistic	p-value	No. lags[a)]	test-statistic	p-value
Aggregate US	0.022	0.883	1	0.460	0.650
Alabama	0.613	0.434	1	-0.224	0.823
Arizona	0.155	0.693	1	-0.128	0.898
Arkansas	0.159	0.690	1	1.670	0.095
California	0.479	0.489	1	-0.116	0.908
Colorado	0.122	0.727	1	0.249	0.803
Florida	0.017	0.897	1	-0.698	0.485
Georgia	0.003	0.954	1	0.249	0.803
Idaho	0.015	0.901	1	0.723	0.470
Illinois	0.203	0.652	1	-1.645	0.100
Indiana	1.670	0.196	1	-0.224	0.823
Iowa	0.197	0.657	1	-0.224	0.823
Kansas	0.584	0.445	1	0.842	0.400
Kentucky	0.239	0.625	1	0.249	0.803
Louisiana	0.058	0.809	1	-0.698	0.485
Maine	1.047	0.306	1	0.249	0.803
Maryland	0.006	0.936	1	0.249	0.803
Massachusetts	1.287	0.257	1	0.723	0.470
Michigan	0.333	0.564	1	-0.698	0.485
Minnesota	0.001	0.976	1	-1.645	0.100
Mississippi	0.984	0.321	1	-2.118	0.034
Missouri	0.191	0.662	1	0.357	0.721
Montana	0.709	0.400	1	-2.118	0.034
Nebraska	0.217	0.641	1	-0.698	0.485
Nevada	0.021	0.884	1	0.723	0.470
New Mexico	1.255	0.263	1	-0.224	0.823
New York	7.520	0.023	2	0.357	0.721
North Carolina	0.737	0.391	1	-1.448	0.148
North Dakota	5.297	0.071	2	-0.224	0.823
Ohio	0.034	0.854	1	-0.698	0.485
Oklahoma	2.966	0.085	1	-1.645	0.100
Oregon	0.640	0.424	1	-1.448	0.148
Pennsylvania	5.251	0.072	2	0.723	0.470
South Carolina	0.229	0.632	1	-0.224	0.823
South Dakota	2.929	0.087	1	1.327	0.184
Tennessee	0.215	0.643	1	-0.224	0.823
Texas	3.791	0.052	1	-0.224	0.823
Utah	4.541	0.033	1	-0.698	0.485
Virginia	4.685	0.030	1	-0.224	0.823
Washington	0.476	0.490	1	-0.613	0.540
West Virginia	4.555	0.033	1	0.723	0.470
Wisconsin	0.569	0.451	1	-1.171	0.241
Wyoming	0.088	0.767	1	-0.224	0.823

Notes. The residuals are obtained from regressing lightning on a constant for each of the 42 states over the period 1977-1995. H_0: Residuals are not serially correlated. Lightning is average number of flashes per year per square km, measured at weather stations.

a) Lags selected by Schwarz's information criteria.