Cash and the Economy:
Evidence from India's Demonetization

Online Appendix

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A   MODEL PROOFS

We begin by stating all of the first order conditions for the household:

$$C_{i,t}: \qquad U'(C_{i,t}) = (\lambda_{i,t} + \kappa\theta_{i,t}) P_{i,t}, \qquad (A.1)$$

$$M_{i,t}: \qquad \lambda_{i,t} (1 + \tau'(\eta_{i,t})) = \beta [\lambda_{it+1} + \theta_{it+1}], \qquad (A.2)$$

$$D_{i,t}: \qquad \lambda_{i,t} = \beta R_t \lambda_{it+1}, \qquad (A.3)$$

$$C_{i,t}^N: \qquad P_{i,t}^N C_{i,t}^N = (1-\alpha)P_{i,t}C_{i,t} \qquad (A.4)$$

$$C_{i,t}^T: \qquad P_t^T C_{i,t}^T = \alpha P_{i,t}C_{i,t} \qquad (A.5)$$

$$C_{i,t}^T(\omega): \qquad C_{i,t}^T(\omega) = \left(\frac{P_t^T(\omega)}{P_t^T}\right)^{-\sigma} C_{i,t}^T \qquad (A.6)$$

along with the complementary slackness conditions,

$$\theta_{i,t} \cdot (\kappa P_{i,t}C_{i,t} - M_{it-1} - T_{i,t}^M) = 0, \qquad (A.7)$$

$$h'(f_{i,t}) = -\theta_{i,t}\kappa'(f_{i,t})P_{i,t}C_{i,t}, \qquad (A.8)$$

where $\lambda_{i,t}$ is the Lagrange multiplier on the budget constraint and $\theta_{i,t}$ is the Lagrange multiplier on the CIA constraint. We use the functional form $\tau(\eta_{i,t}) = \frac{\bar{\tau}}{e^{\nu\eta_{i,t}}}$ where $0 < \nu < 1$.

Pre-Demonetization Steady State

The economy in period -1 is in a steady state where because of tax evasion incentives the CIA does not bind, $M_{-1} > \bar{\kappa}P_{-1}C_{-1}$. This requires that $\bar{\kappa}(1 + \varphi(\frac{1}{\beta} - 1)) < \frac{1}{\nu} \ln\left(\frac{\nu\bar{\tau}}{1-\beta}\right)$, that is, that the tax rate $\bar{\tau}$ is sufficiently high relative to the interest rate and to the fraction of spending that needs to be undertaken in cash absent any adoption of financing technology $\bar{\kappa}$.

This assumption reflects the argument made by the Indian government that an important fraction of pre-demonetization cash was 'black money' held for tax evasion purposes.

Proposition A.1 *Pre-demonetization steady state*
In period -1 all regions are in a symmetric zero inflation steady state with $M^s = M_{-1}$, and

1. *The economy is in full employment:*

$$N_{-1} = \bar{N}, \qquad Y_{-1}^T = N_{-1}^T = \alpha \bar{N}, \quad Y_{-1}^N = N_{-1}^N = (1 - \alpha)\bar{N}. \qquad \text{(A.9)}$$

2. *Real money balances are increasing in the level of consumption C and in the labor income tax $\bar{\tau}$ and decreasing in the interest rate $R_{-1} = 1/\beta$:*

$$\frac{M_{-1}}{P_{-1}} = \frac{\eta_{-1} C_{-1}}{(1 + \varphi(R_{-1} - 1))}, \qquad \eta_{-1} = \frac{1}{\nu} \ln\left(\frac{\nu \bar{\tau}}{1 - (1/R_{-1})}\right). \qquad \text{(A.10)}$$

3. *Nominal wages and prices are given by:*

$$W_{-1} = \frac{M_{-1}}{\bar{N}\eta_{-1}}, \quad P_{-1}^T = P_{-1}^N = (1 + \varphi(\beta^{-1} - 1))\frac{M_{-1}}{\bar{N}\eta_{-1}}. \qquad \text{(A.11)}$$

■

With a constant level of money supply in the economy, the wage friction does not bind and the economy is in full employment with a fraction α of labor employed in the traded sector and $(1 - \alpha)$ in the non-traded sector.

Proof

Begin by assuming $\theta_{-1} = 0$. We will later derive the parameter restrictions under which this is the case. From the F.O.C. for cash in the steady state, we have that:

$$\eta_{-1} = \frac{1}{\nu} \log\left(\frac{\nu \bar{\tau}}{1 - \beta}\right)$$

From the definition of η it the follows that:

$$W_{-1} = \frac{M_{-1}}{N_{-1}\eta_{-1}}$$

From the F.O.C. for consumption in a zero inflation steady state it follows that real consumption is constant which implies that labor is constant. This further implies that

wages are constant so the downward nominal rigidity is not binding and the economy is in full employment, i.e. $N_{-1} = \bar{N}$

Now, again using the definition of η_{-1} and the firms optimality conditions we have:

$$W_{-1} = \frac{M_{-1}}{\bar{N}\eta_{-1}}, \qquad P_{-1}^T = P_{-1}^N = (1 + \varphi(\beta^{-1} - 1))\frac{M_{-1}}{\bar{N}\eta_{-1}}$$

As prices for both types of goods are the same, using the F.O.C. for tradable and non-tradable goods we have that:

$$\frac{C_{-1}^N}{C_{-1}^T} = \frac{1 - \alpha}{\alpha}$$

Applying market clearing conditions, $C_{-1}^T = N_{-1}^T$, $C_{-1}^N = N_{-1}^N$, $N_{-1}^N + N_{-1}^T = \bar{N}$ and rearranging yields:

$$N_{-1}^N = (1 - \alpha)\bar{N}, \qquad N_{-1}^T = \alpha\bar{N}$$

From where point 1 follows immediately. For the remaining part of point 2 take the optimal price of the non-tradable good producer, multiply both sides by $(1 - \alpha)\bar{N}$ and use the market clearing condition for this good:

$$P_{-1}^N C_{-1}^N = (1 - \alpha)(1 + \varphi(\beta^{-1} - 1))\frac{M_{-1}}{\eta_{-1}}$$

Using the bundling condition for non-tradable goods and rearranging yields point 2:

$$\frac{M_{-1}}{P_{-1}} = \frac{\eta_{-1}C_{-1}}{1 + \varphi(\beta^{-1} - 1)}$$

It is only left to show that indeed $\theta_{-1} = 0$. We may rearrange this last expression as:

$$P_{-1}C_{-1} = (1 + \varphi(\beta^{-1} - 1))\frac{M_{-1}}{\eta_{-1}}$$

Now the cash-in-advance constraint being slack can equivalently be stated as:

$$\bar{\kappa}(1 + \varphi(\beta^{-1} - 1)) < \eta_{-1}$$

And substituting the value for η_{-1}:

$$\bar{\kappa}(1 + \varphi(\beta^{-1} - 1)) < \frac{1}{\nu}\log\left(\frac{\nu\bar{\tau}}{1 - \beta}\right)$$

A restriction on parameters that we impose.

Proof of proposition 1

Start by assuming that both the cash-in-advance constraint and the downward nominal rigidity are binding. Now using the cash-in-advance constraint, the bundling condition for the non-tradable good, and the market clearing condition for this good we find that:

$$\bar{\kappa}\frac{P_0^N N_0^N}{1-\alpha} = M_0$$

$$\Leftrightarrow N_0^N = \frac{(1-\alpha)M_0}{\bar{\kappa}P_0^N}$$

Using the optimality condition for the producer of the non-tradable good, the nominal rigidity, and the fact that interest rates remain constant, we can substitute for the price of the non-tradable good and obtain:

$$N_0^N = \frac{M_0}{\gamma M_{-1}} \cdot \frac{\eta_{-1}}{\kappa(1+\varphi(\beta^{-1}-1))}(1-\alpha)\bar{N}$$

$$= \frac{Z}{\gamma} \cdot \frac{\eta_{-1}}{\bar{\kappa}(1+\varphi(\beta^{-1}-1))}(1-\alpha)\bar{N}$$

And through the same procedure:

$$N_0^T = \frac{Z}{\gamma} \cdot \frac{\eta_{-1}}{\bar{\kappa}(1+\varphi(\beta^{-1}-1))}\alpha\bar{N}$$

Finally:

$$\frac{Y_0}{Y_{-1}} = \frac{Z}{\gamma} \cdot \frac{\eta_{-1}}{\bar{\kappa}(1+\varphi(\beta^{-1}-1))}$$

which proves point 1. Aggregate price level is given by:

$$P_0 = \frac{(1+\varphi(\beta^{-1}-1))\gamma W_{-1}}{\alpha^\alpha(1-\alpha)^{1-\alpha}}$$

Now, real lending to firms is given by:

$$\frac{B_0^f}{P_0} = \frac{\alpha^\alpha(1-\alpha)^{1-\alpha}\varphi N_0}{1+\varphi(\beta^{-1}-1)}$$

Similarly:

$$\frac{B^f_{-1}}{P_{-1}} = \frac{\alpha^\alpha (1-\alpha)^{1-\alpha} \varphi \bar{N}}{1 + \varphi(\beta^{-1} - 1)}$$

Since $N_0 < \bar{N}$,

$$\frac{B^f_0}{P_0} < \frac{B^f_{-1}}{P_{-1}}$$

It is only left then to show that demonetization makes the downward nominal rigidity and the cash-in-advance constraint binding. Multiplying both sides of the optimality condition of non-tradable goods producer by $C^N_{i,0} = N^N_0$ yields:

$$P^N_0 C^N_0 = (1 + \varphi(\beta^{-1} - 1))N^N_0 W^N_0.$$

Now, using the cash-in-advance constraint and the bundling condition for non-tradable goods we find that:

$$(1 - \alpha)\frac{M_{i,0}}{\bar{\kappa}} = (1 + \varphi(\beta^{-1} - 1))N^N_0 W_0$$

Since demonetization is homogeneous, regional trade balances remain at zero so we may use the same procedure for tradeable goods to find that:

$$\alpha\frac{M_0}{\bar{\kappa}} = (1 + \varphi(\beta^{-1} - 1))N^T_0 W_0$$

Adding these two up, using labor markets' clearing condition and rearranging yields:

$$W_0 = \frac{M_0}{\bar{\kappa}(1 + \varphi(\beta^{-1} - 1))N_0}$$

Now we derive the condition under which if $N_0 = \bar{N}$ then $W_0 < \gamma W_{-1}$:

$$\frac{M_0}{\bar{\kappa}(1 + \varphi(\beta^{-1} - 1))\bar{N}} < \frac{\gamma M_{-1}}{\bar{N}\eta_{-1}}$$

$$\Leftrightarrow Z\frac{\eta_{-1}}{\bar{\kappa}(1 + \varphi(\beta^{-1} - 1))} < \gamma$$

Under this conditions $N_0 < \bar{N}$ and $W_0 = \gamma W_{-1}$ as in point 3. Finally, for the cash-in-advance constraint to hold, we have that:

$$\frac{\kappa}{M_0} = \lambda_0 + \bar{\kappa}\theta_0$$

$$\lambda_0(1 + \tau'(\eta_{i,0})) = \beta\lambda_1$$

Notice that we have used the fact that the cash-in-advance constraint is not expected to bind in $t > 0$. From these two equations it follows that:

$$\theta_0 = \frac{1}{M_0} - \frac{\beta \lambda_{i,1}}{\bar{\kappa}(1 + \tau'(\eta_0))}$$

From the problem at $t = 1$ we have that:

$$\lambda_1 = \frac{\eta_1}{(1 + \varphi(\beta^{-1} - 1))M_1}$$

Now, rearranging, we find that $\theta_0 > 0$ may equivalently be written as:

$$\frac{M_1}{M_0} > \frac{\beta \eta_1}{\bar{\kappa}(1 + \tau'(\eta_0))(1 + \varphi(\beta^{-1} - 1))}$$

Then, given this parameter restrictions, the cash-in-advance constraint is binding at $t = 0$.

Proof of proposition 2

We will again start by assuming that the downward nominal rigidity is binding and then show conditions under which this is the case. We now have that in every region the optimality condition for the producers of the non-tradable good is given by:

$$P_{i,0} = (1 + \varphi(\beta^{-1} - 1))\gamma W_{-1}$$
$$= (1 + \varphi(\beta^{-1} - 1))\gamma \frac{M_{-1}}{\eta_{-1}\bar{N}}$$

Multiplying both sides by $C_{i,0} = N_{i,0}^N$, using the cash-in-advance constraint, and the bundling condition for the non-tradable good yields:

$$(1 - \alpha)\frac{M_{i,0}}{\bar{\kappa}} = (1 + \varphi(\beta^{-1} - 1))\gamma \frac{M_{-1}}{\eta_{-1}\bar{N}}N_{i,0}^N$$

Rearranging and using the definition of Z_i:

$$N_{i,0}^N = \frac{(1 - \alpha)Z_i}{\gamma}\frac{\eta_{-1}\bar{N}}{\bar{\kappa}(1 + \varphi(\beta^{-1} - 1))}$$

As wages are constant across regions, so are the prices for tradeable varieties which implies that $C_{j,0}^T(\omega) = C_{j,0}^T$. Now, using the tradable good producers' optimality condition, the cash-

in-advance constraint, and the bundling condition for tradable goods, it is possible to find that:

$$\frac{\alpha}{\bar{\kappa}} Z_{j,0} = \frac{(1 + \varphi(\beta^{-1} - 1)\gamma)}{\bar{N}\eta_{-1}} C_{j,0}^T(i)$$

Integrating over j in both sides and using the market clearing condition for tradable variety i yields:

$$\frac{\alpha}{\bar{\kappa}} Z = \frac{(1 + \varphi(\beta^{-1} - 1))\gamma}{\bar{N}\eta_{-1}} N_{i,0}^T$$

$$\Leftrightarrow N_{i,0}^T = \frac{\alpha Z}{\gamma} \frac{\eta_{-1}\bar{N}}{\bar{\kappa}(1 + \varphi(\beta^{-1} - 1))}$$

Given these values for $N_{i,0}^T$ and $N_{i,0}^N$, and the production functions, point 1 in the proposition follows.

Point 2 follows directly from the fact that $B_{i,0}^f = \varphi\gamma W_{-1} N_{i,0}$ and $P_0 = \alpha^\alpha(1 - \alpha)^{1-\alpha}(1 + \varphi(\beta^{-1} - 1))\gamma W_{-1}$. It is only left to prove that $W_{i,0} = \gamma W_{-1}$, i.e. the downward nominal rigidity is binding. The complementary slackness condition is given by:

$$(\bar{N} - N_{i,0})(W_{i,0} - \gamma W_{i,-1}) = 0$$

From point 1 we have that if:

$$\gamma > \left(\alpha Z + (1 - \alpha)\tilde{Z}\right) \frac{\eta_{-1}}{\bar{\kappa}(1 + \varphi(\beta^{-1} - 1))}$$

Where $\tilde{Z} = \max_j Z_j$, then $W_{i,0} = \gamma W_{-1}$ in every region i. With heterogenous money shocks regions with lower money replacement rates enter period 1 with higher financial wealth. The evolution of savings is given by $D_{j,1} - D_0 = (Y_0^T(\omega) - C_{j,0}^T(\omega)) + (R_0 - 1)D_0$, where $(Y_0^T(\omega) - C_{j,0}^T(\omega))$ is the trade balance and $(R_0 - 1)D_0$ the interest earning on deposits from the previous period.[1] Because $Y_0^T(\omega)$ depends on aggregate demand and is the same across regions, but $C_{j,0}^T(\omega))$ is increasing in Z, regions with lower Z run trade balance surpluses in period 0. This means that starting in period 1 low Z regions have permanently higher wealth, and higher consumption by the amount of the interest earning on their deposits $(\frac{1}{\beta} - 1)D_{j,1}$. An alternative, would be to allow the government to use lump-sum taxes to undo the dispersion in wealth in period 1. This would have no meaningful impact on the

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[1]This is assuming that government lump-sum transfers in each region exactly equal the labor income tax paid plus region specific money infusion, that is there is no redistribution.

period 0 solution.

Numerical Illustration with Endogenous κ

We use the following functional forms: $\kappa(f) = \bar{\kappa}e^{-\zeta f}$ and $h(f) = \frac{a}{2}f^2$. Now it follows that $\theta_{i,0} = \frac{af_{i,0}}{\zeta M_{i,0}}$. Further:

$$\left(\frac{af_{i,0} - \zeta}{\zeta}\right)\kappa(f_{i,0})(1 + \tau'(\eta_{i,0})) + \beta\lambda_{i,1}M_{i,0} = 0$$

$$\eta_{i,0} = \frac{Z_i}{\alpha\bar{Z} + (1-\alpha)Z_i}\kappa(f_{i,0})(1 + \varphi(\beta^{-1} - 1))$$

By substituting the second equation of this set in the first one we arrive at a single equation in $f_{i,0}$. We then have that, $f_{i,0} = \Psi(\mathcal{I}, Z_i)$ where $\mathcal{I}$ satisfies $\mathcal{I} = \int \psi(\mathcal{I}, Z_j)dj$. For the numerical solution we consider a discrete distribution for Z_i with finite support $\{Z_1, ..., Z_S\}$ and $\mathbb{P}(Z < Z_s) = w_s$, of course, $w_S = 1$. Notice that in this case $\mathcal{I} = \sum_{s=1}^{S} \frac{Z_s}{\kappa(f_{s,0})}\Delta w_s$. We employ the parameter values shown in table A.1.

Parameter	Value
a	0.01
α	0.4
$\bar{\kappa}$	1
$\bar{\tau}$	0.2
β	0.98
γ	1
M_{-1}	1
M_1	1
$\bar{N}$	1
ν	2.5
φ	0.9
ζ	10

s	Z_s	w_s
1	0.0431	0.01
2	0.089	0.05
3	0.126	0.1
4	0.21	0.25
5	0.307	0.5
6	0.464	0.75
7	0.636	1

TABLE A.1: Parameter values

Figure B.1: Aggregate New Notes

B   DATA APPENDIX

B.A   Data Benchmark
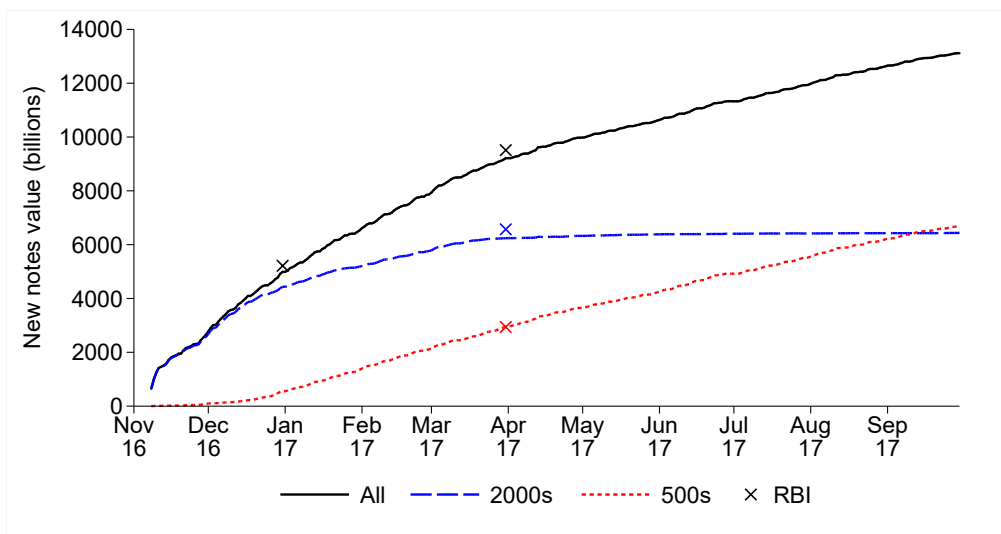
The currency chest data from the RBI are confidential and not publicly available. Figure B.1 plots the aggregate value of new notes in our data over time, using the definitions given in equation (11) and equation (12). For comparison, the xs show the value of new notes as stated in RBI (2017a). Our measures track the RBI official reporting extremely closely in both levels and differences.

B.B   Nightlights versus Electricity

Nightlight activity correlates with real economic activity because it reflects nighttime electricity use. Figure B.2 compares aggregate nightlight activity and total electricity use in the quarters surrounding demonetization. Both variables fall in the quarter of demonetization. However, only nightlight activity rebounds sharply in $2017Q1$, demonstrating that nightlight activity and electricity use can sometimes diverge.

We now discuss why nightlight activity remains a valid measure for our *cross-sectional* analysis despite the difficulties that arise in using *aggregate* nightlight activity to infer the

10

Figure B.2: Aggregate Nightlight Activity and Electricity Use
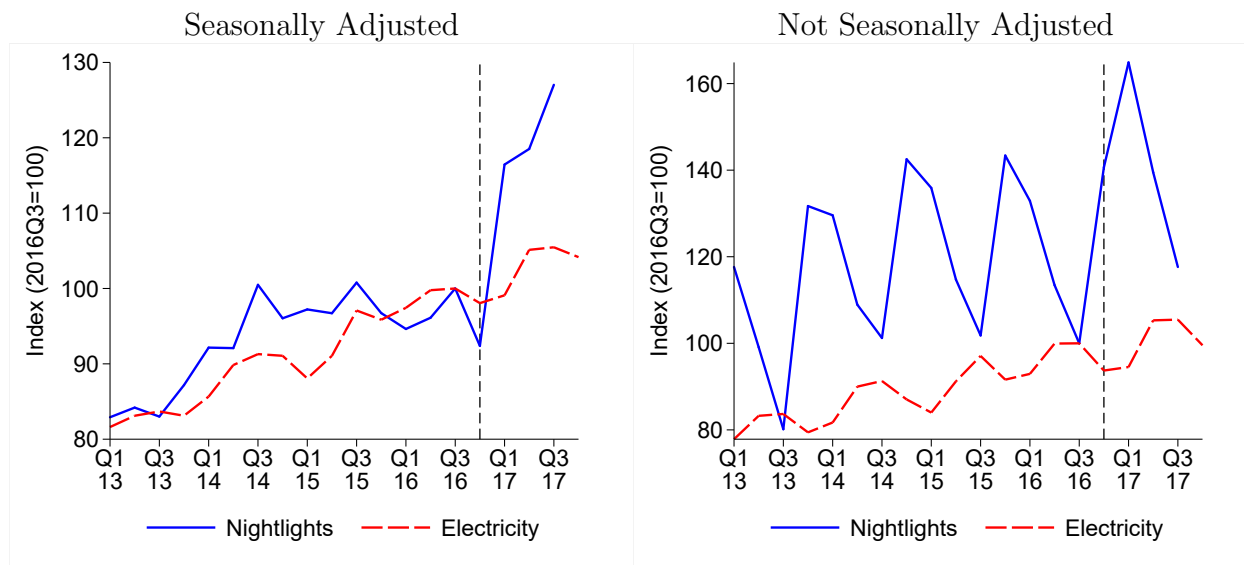
Notes: Seasonal adjustment of nightlight activity is done at the district level as described in the main text of the paper. Seasonal adjustment of electricity is done at the aggregate level by regressing electricity on four quarterly categorical variables and a linear time-trend.

impact of demonetization. Let $Y_{i,t}$ denote total nightlight activity in district i in quarter t. We decompose nightlight activity into a number of factors:

$$Y_{i,t} = M_{i,t} C_{i,t} U_{i,t},$$

where $C_{i,t}$ denotes electric capacity and reflects long-run factors such as the degree of electrification, $U_{i,t}$ denotes utilization, and $M_{i,t}$ denotes the component of nightlight activity unrelated to economic activity (e.g. from not removing stray light or changing seasonal patterns due to the satellite collection). For simplicity, we will refer to the component $M_{i,t}$ as measurement error. Let Δ denote the difference operator, a lower case variable the log of the uppercase variable, and $Y_t = \sum_i Y_{i,t}$ aggregate nightlight activity. Then it is clear that Δy_t could reflect growth in the high frequency component related to economic activity, Δu_t, the long-run component Δc_t, or measurement error Δm_t.

Importantly, under our maintained assumption that severity of demonetization was as good as randomly assigned, cross-sectional differences in nightlight activity growth isolate the effect of demonetization on the high frequency business cycle component. Specifically, we have that $z_{i,t}$ is uncorrelated with $\Delta m_{i,t}$ and $\Delta c_{i,t}$. Therefore, the coefficient from a regression of $\Delta y_{i,t}$ on $z_{i,t}$ is equal to the coefficient from a regression of $\Delta u_{i,t}$ on $z_{i,t}$; the regression captures only the cross-sectional effect of demonetization on the component related to high

TABLE B.1: Nightlight Growth, Electricity Growth, and Demonetization Severity, 2016Q4

	Dep. var.: log change in nightlight intensity			
Aggregation:	District	State		
	(1)	(2)	(3)	(4)
Demonetization shock	1.20**	0.87$^+$		0.01
	(0.37)	(0.41)		(0.47)
Log change in electricity use			3.38**	3.38**
			(0.83)	(1.03)
Weight	None	Districts	Districts	Districts
R^2	0.11	0.11	0.35	0.35
Observations	473	33	33	33

Notes: The dependent variable is the log point change in nightlights from 2016Q3 to 2016Q4 multiplied by 10. Column (1) reproduces the baseline result at the district level. Observations in columns (2)-(4) are collapsed to the state level and the regression is weighted by the number of districts in each state. Standard errors in parentheses. **,*,$^+$ denote significance at the 1, 5, or 10 percent level.

frequency economic activity.

Finally, we use cross-sectional data on electricity use to validate the cross-sectional night-light specification in the quarter of demonetization. Quarterly data on electricity use by district do not exist. Instead, we use state-level data on electricity use to show that demonetization affects nightlight intensity because demonetization affects electricity consumption. Table B.1 summarizes the results. Column (1) reproduces the baseline coefficient from the cross-district regression in 2016Q4 of nightlight growth on the log of the demonetization shock, z. Column (2) reports the same regression specification but after collapsing the data to the state level. To make the specification comparable to the district-level specification, we weight the regression by the number of districts in each state. The table shows a similar magnitude of response when using cross-state variation. Column (3) regresses nightlight growth on the growth rate of electricity use. The two variables are strongly correlated with each other. Finally, column (4) estimates a horse-race regression. Controlling for electricity growth makes the coefficient on demonetization essentially zero. This is exactly what should happen if nightlight growth is related to demonetization only because electricity consumption is related to demonetization. Thus, the effect of demonetization on nightlight use in the cross-state regression goes entirely through its effect on electricity use.

TABLE B.2: Main Results with Alternative Measure of $Z_{i,t}$

Dep. var.	Baseline		Soiled note imputation		Large note share=0.87	
	$\beta_{1,t}$	s.e.	$\beta_{1,t}$	s.e.	$\beta_{1,t}$	s.e.
ATM withdrawals	3.04**	0.85	3.26**	0.70	3.37**	1.09
Employment	0.34**	0.09	0.32**	0.08	0.41**	0.09
Nightlights	1.20**	0.37	1.02*	0.41	1.28*	0.45
E-Wallet	−2.78**	0.53	−2.74**	0.39	−3.18**	0.69
POS	−3.46*	1.31	−4.10**	1.00	−4.04*	1.54
Deposits	−0.21*	0.09	−0.24**	0.07	−0.25*	0.10
Bank credit	0.20**	0.05	0.16*	0.05	0.23**	0.06

Notes: The left panel reproduces the coefficients without controls in tables V to VIII. The middle panel reports the coefficients and standard errors based on a measure of the demonetization shock $z_{i,t}$ which allocates the national quantity of small (100 rupee and below) notes across districts using the district shares of small soiled notes during 2014 and 2015. The right panel reports the coefficients and standard errors based on a measure of the demonetization shock $z_{i,t}$ which assumes demonetized notes were 87% of pre-demonetization currency everywhere. Standard errors clustered by state using the "LZ2" bias-reduction modification suggested by Imbens and Kolesár (2016). **,*,+ denote significance at the 1, 5, or 10 percent level based on a t-distribution with degrees of freedom for the currency replacement variable shown in the row "Treatment BM df".

B.C Alternative Assumptions for Demonetized Note Share

Table B.2 reports our main results using an alternative measure of the demonetization shock. The left panel reproduces the coefficients without controls in tables V to VIII. The right panel reports the coefficients and standard errors based on a measure of the demonetization shock $Z_{i,t}$ which assumes demonetized notes were 87% of pre-demonetization currency everywhere.

B.D Heterogeneous Treatment Effects

This appendix explores heterogeneous treatment effects. Specifically, for a variable I_i, we first normalize the variable to have zero mean and unit variance in the regression sample and then include both the level and the interaction of the normalized variable in the regression. Thus, the coefficient on the interaction term has the interpretation of the additional effect of the severity of demonetization for a district one standard deviation above the mean of the interacted variable. We consider two proxies for financial sophistication and urbanization: GDP per capita and population density. Neither interacts in an economically or statistically significant manner with the severity of demonetization.

TABLE B.3: Interaction with GDP per Capita

Dep. var.	ATM	Nightlights	Emp.	E-wallet	POS	Deposits	Credit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$z_{i,t}$	3.09**	1.16**	0.36**	−2.94**	−4.19*	−0.30**	0.22**
	(0.98)	(0.27)	(0.08)	(0.61)	(1.42)	(0.08)	(0.05)
Interaction	0.22	0.22	0.12	−0.13	−1.59	−0.12	−0.03
	(0.48)	(0.25)	(0.12)	(0.49)	(0.98)	(0.07)	(0.07)
$z_{i,t} \times$ Interaction	0.09	0.19	0.08	0.17	0.08	0.05	−0.05
	(0.46)	(0.20)	(0.12)	(0.46)	(0.84)	(0.06)	(0.06)
R^2	0.13	0.11	0.03	0.21	0.09	0.16	0.13
Clusters	31	31	22	29	31	30	30
Observations	529	535	407	511	520	529	529

TABLE B.4: Interaction with Population Density

Dep. var.	ATM	Nightlights	Emp.	E-wallet	POS	Deposits	Credit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$z_{i,t}$	3.08**	1.20**	0.33**	−2.75**	−3.04*	−0.27**	0.18**
	(0.84)	(0.31)	(0.09)	(0.57)	(1.22)	(0.08)	(0.05)
Interaction	0.37	0.06	−0.20	1.08	7.50+	−0.38*	−0.26
	(1.95)	(0.84)	(0.47)	(1.56)	(2.98)	(0.14)	(0.21)
$z_{i,t} \times$ Interaction	0.18	0.08	−0.22	1.01	7.71+	−0.19	−0.25
	(1.86)	(0.74)	(0.44)	(1.46)	(2.55)	(0.10)	(0.19)
R^2	0.13	0.10	0.03	0.21	0.06	0.10	0.12
Clusters	31	31	22	29	31	30	30
Observations	529	535	407	510	520	528	528

B.E Aggregate Implications

Figure B.3 reports the actual paths of employment and nightlights and the counterfactual paths implied by the aggregation of our cross-sectional estimates. In each plot, the blue line

Figure B.3: Counterfactual Employment and Nightlights
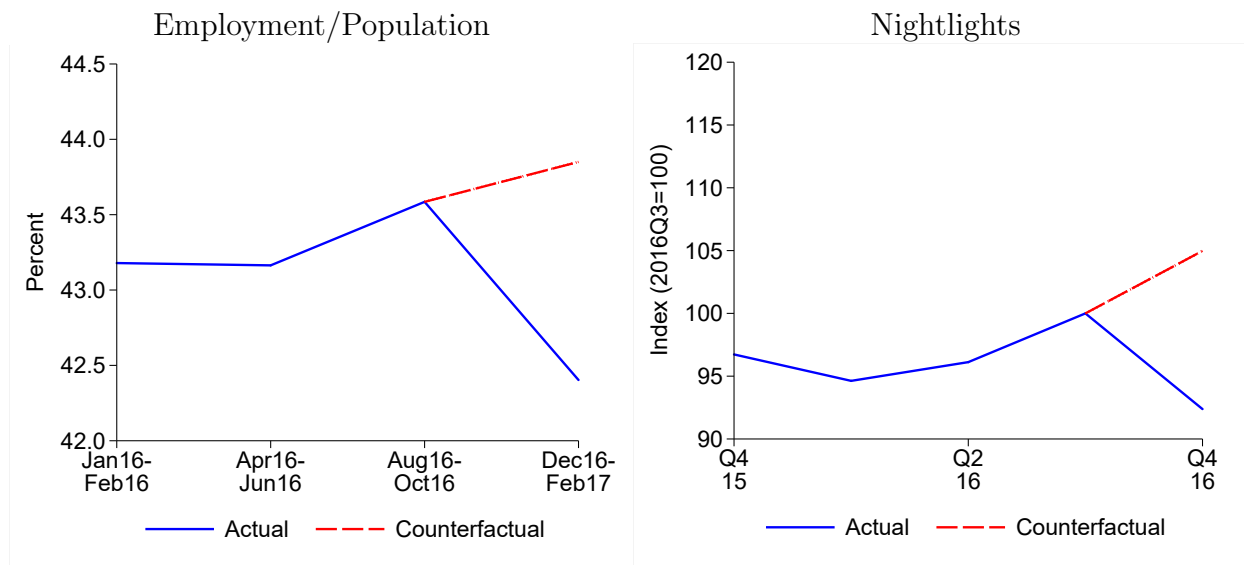
Notes: the blue solid lines in each figure show the time path of actual data. The red dashed lines show the counterfactual time path implied by the aggregation of our cross-sectional estimates.

shows the actual data and the red dashed line the implied counterfactual.

B.F   Measurement Error in the Demonetization Shock

In this appendix we show that measurement error would attenuate the empirical results toward zero.

Recall our baseline cross-sectional specification:

$$\Delta y_{i,t} = \beta_{0,t} + \beta_{1,t} z_{i,treatment} + \Gamma_t X_i + \epsilon_{i,t}, \tag{B.1}$$

where $\Delta y_{i,t} = \ln Y_{i,t} - \ln Y_{i,baseline}$ denotes the change in the natural logarithm of an outcome variable relative to the period before demonetization, $z_{i,treatment} = \ln Z_{i,treatment}$ is the log of the demonetization shock, and X_i is a vector containing any controls. We construct $z_{i,treatment}$ by aggregating across currency chests in district i.

Now suppose $z_{i,treatment}$ is a noisy measure of the true demonetization shock, $z^*_{i,treatment}$,

$$z_{i,treatment} = z^*_{i,treatment} + e_i, \tag{B.2}$$

where the measurement error e_i is mean zero and independent of $z^*_{i,treatment}$. The measurement error e_i could for example stem from not adjusting for chests serving multiple districts,

or from not observing individuals who deposit demonetized notes in banks in other districts to try to circumvent deposit requirements. Thus, the true data generating process replaces $z_{i,treatment}$ in equation (B.1) with $z^*_{i,treatment}$:

$$\Delta y_{i,t} = \beta^*_{0,t} + \beta^*_{1,t} z^*_{i,treatment} + \Gamma^*_t X_i + \epsilon^*_{i,t}, \tag{B.3}$$

where $E[\epsilon^*_{i,t} e_i] = E[z^*_{i,treatment} \epsilon^*_{i,t} | X_i] = 0$.

To study the consequence of estimating equation (B.1) instead of equation (B.3), let $w^\perp_{i,t}$ denote the residual from projecting a variable w_i on a constant and X_i and $plim$ the probability limit. Then the OLS coefficient $\hat{\beta}_{1,t}$ from estimating our baseline specification is:

$$
\begin{aligned}
plim\,\hat{\beta}_{1,t} &= \frac{\mathrm{Cov}\left(\Delta y^\perp_{i,t}, z^\perp_{i,treatment}\right)}{\mathrm{Var}\left(z^\perp_{i,treatment}\right)} \\
&= \frac{\mathrm{Cov}\left(\Delta y^\perp_{i,t}, z^{*\perp}_{i,treatment} + e^\perp_i\right)}{\mathrm{Var}\left(z^{*\perp}_{i,treatment} + e^\perp_i\right)} \\
&= \frac{\mathrm{Var}\left(z^{*\perp}_{i,treatment}\right)}{\mathrm{Var}\left(z^{*\perp}_{i,treatment} + e^\perp_i\right)} \frac{\mathrm{Cov}\left(\beta^*_{1,t} z^{*\perp}_{i,treatment} + \epsilon^{*\perp}_{i,t}, z^{*\perp}_{i,treatment} + e^\perp_i\right)}{\mathrm{Var}\left(z^{*\perp}_{i,treatment}\right)} \\
&= (1-b) \times \beta^*_{1,t}, \tag{B.4}
\end{aligned}
$$

where in the last line we define $b = \mathrm{Var}\left(e^\perp_i\right) / \mathrm{Var}\left(z^{*\perp}_{i,treatment} + e^\perp_i\right) \in [0,1]$ as the attenuation bias coefficient which is the contribution of the measurement error to the overall variance in the measured demonetization shock (after partialling out covariates).

Using equation (B.4), we see that the estimated coefficient from our baseline specification equation (B.1) is equal to the product of $(1-b)$ and the true coefficient $\beta^*_{1,t}$. Since $b \in [0,1]$, we have the result that measurement error due to misclassification of flows to currency chests which serve multiple districts or location of deposited notes would bias our results toward zero. The only assumptions made are that the mismeasurement is uncorrelated with the true measure of cash shortage in each district and with the unobserved determinants of the outcome variable.

B.G   *Seasonality in CMIE Data*

Insufficient historical coverage (data start in 2016) and the sampling pattern of the CMIE data (not every district surveyed every month) make district-level seasonal adjustment of the CMIE data impossible. However, any aggregate seasonal pattern is "differenced out" in the cross-sectional estimation and affects only the constant term in the regression. There remains

the issue of district-specific seasonality. Such seasonality is classical left-hand-side measurement error and will inflate the regression standard errors but not bias the point estimates. Formally, let $\Delta s_{i,t}$ denote the (demeaned) district-specific log change in the seasonal factor and $\Delta y_{i,t}^*$ (demeaned) seasonally-adjusted employment growth, so that $\Delta y_{i,t}^* = \Delta y_{i,t} + \Delta s_{i,t}$ with $E[\Delta s_{i,t} z_{i,treatment}] = 0$. Comparing the two regression models:

$$\Delta y_{i,t}^* = \beta_{0,t}^* + \beta_{1,t}^* z_{i,treatment} + \Gamma_t^* X_i + \epsilon_{i,t}^*, \tag{B.5}$$

$$\Delta y_{i,t} = \beta_{0,t} + \beta_{1,t} z_{i,treatment} + \Gamma_t X_i + \epsilon_{i,t}, \tag{B.6}$$

it is apparent that the second equation is equivalent to the first with $\epsilon_{i,t} = \epsilon_{i,t}^* - \Delta s_{i,t}$. Therefore, $plim \hat{\beta}_{1,t} = plim \hat{\beta}_{1,t}^*$, and $\text{Var}\left(\hat{\beta}_{1,t}\right) > \text{Var}\left(\hat{\beta}_{1,t}^*\right)$ because the residual variance is larger.