Online Appendix to
Credit Rationing and Pass-Through in Supply Chains:
Theory and Evidence from Bangladesh

NOT FOR PUBLICATION

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1 Extensions of the Model: Alternative Financing and Trading Options for the Traders

1.1 Traders and Bank Financing

The model in the paper assumes that the traders rely on DOTs for oil on credit and do not use bank credit in equilibrium. In this section of the appendix, we argue that, under plausible parameter values, the main results continue to hold when we augment the financing and trading options available to the traders.

First, consider the consequences of allowing the traders to purchase DOs in cash at $T = 0$ from a DOT, financing this with a bank loan. Suppose we are in the hierarchical Cournot equilibrium studied in the previous section, with an equilibrium bundled price of P_d^{**}. Then there is no scope for a trader to switch to buying any DO from a DOT in cash instead of credit.

The trader would need to pay a cash price P_c of at least $\frac{P_d^{**}}{1+i_d}$ to ensure that the DOT is at least as well off compared with the trade credit transaction, and repay the bank $P_c(1+i_b)$. The latter is at least $P_d^{**}\frac{1+i_b}{1+i_d}$, which is bigger than P_d^{**}.

Next, consider a trader buying a DO directly from a refiner on cash at the equilibrium price P_r^{**}, and finance this with a bank loan. This would be not be profitable if the following inequality holds:

$$1+i_b > \frac{P_t^{**}-C_t}{P_r^{**}} - \left(\frac{R_d}{R_b}\right)\frac{P_t^{**}-P_d^{**}-C_t}{P_d^{**}} \tag{1}$$

Another possibility is that instead of substituting for trade credit, the trader supplements it with additional DO purchases in cash directly from the refiners by borrowing from banks. This requires paying refiners a cash price of P_r^{**}, and repaying the bank $P_r^{**}(1+i_b)$. The trader would not benefit from this deviation if the equilibrium consumer price P_t^{**} is smaller than $P_r^{**}(1+i_b)$, i.e.,

$$1+i_b > \frac{P_t^{**}}{P_r^{**}} \tag{2}$$

Hence the equilibrium derived above continues to prevail if the interest cost of borrowing from banks is high enough so that it outweighs the benefits from avoiding the DOT markups. Note that inequality (2) is a sufficient condition for inequality (1) to hold. Using data from a 2013 survey of oil traders in Bangladesh that we conducted (Emran et al. (2015)), we can check whether inequality (2) is satisfied. The ratio of wholesale price (P_t^{**}) to refiner price (P_r^{**}) is 1.097, while the estimate for $1+i_b$ is 1.18 as the average bank interest rate paid by the traders is 18 percent.[1] Thus, inequality (2) is satisfied in 2013 data for wholesale traders.

[1]The 18 percent is based on the interest rates reported by the traders. The average interest rates on short-term bank loans reported by Bangladesh Bank is 13 percent in the post-reform period implying that $1+i_b = 1.13$.

1.2 Extension of the Model, with both Credit Constrained and Unconstrained Traders

We now consider an extension of the model in a different direction, where some traders are credit constrained, and others are not. Suppose there are N_{tu} unconstrained traders, and N_{tc} constrained traders. The two categories of traders (subscript 'u' for unconstrained, and 'c' for constrained) differ with respect to their ability to commit to repaying credit-based transactions to the DOTs, with respective default penalties R_{ud}, R_{ub} and R_{cd}, R_{cb} where the subscripts 'd' and 'b' refer to credit from the DOTs and the banks respectively. So R_{ud}, R_{ub} are large enough that the borrowing constraints of the unconstrained traders never bind, while R_{cd}, R_{cb} are substantially smaller so these represent their respective credit limits with the DOTs and the banks respectively. As before, $R_{cd} > R_{cb}$ and $i_d < i_b$.

There are thus two markets for sale of DOs by the DOTs to the traders: one in cash, and the other bundled with credit. Each DOT decides how much to sell in each of these two markets. The cash price $P_{d\$}$ is paid at period $T = 0$, while the credit price P_d is paid at $T = 1$.

We claim that every sub-game perfect equilibrium of this model must be characterized by $P_{d\$}(1 + i_d) = P_d$, i.e., an implicit interest rate on trade credit of i_d. The proof is as follows. If there exists an equilibrium where $P_{d\$}(1 + i_d) < P_d$, the demand for cash purchases must be positive, as the unconstrained traders would strictly prefer to buy in cash. However, the DOTs would not want to supply any DOs on cash, as they strictly prefer to sell on credit. Conversely, when $P_{d\$}(1 + i_d) > P_d$ both types of the traders strictly prefer to buy on credit.[2] But dealers now prefer to sell only in cash, so the cash-based market cannot clear.

Next observe that every subgame perfect equilibrium is the outcome equivalent to the one in which all DOs are sold to traders on credit. This is because the DOTs and the unconstrained traders are indifferent between cash and credit, while the constrained traders strictly prefer to buy on credit (using a similar argument to the one in the previous paragraph). Hence, without loss of generality, the model reduces to one in which all DOs are sold by DOTs on credit. As

[2]For the unconstrained traders this is obvious; for the constrained traders buying in cash involves borrowing from banks and paying a higher interest rate, while subject to a lower credit limit, so is strictly dominated by the option of buying on credit from dealers.

N_{tu} approaches zero while N_{tc} is fixed, the equilibrium outcomes of the model will approach the symmetric model in the previous section where credit constraints are binding for all traders. And conversely, if N_{tc} approaches zero while N_{tu} is fixed, they will approach the one where they are all not binding. In general if both types of traders co-exist, a hybrid equilibrium will emerge, for which it is difficult to obtain closed-form solutions.

If traders are able to buy directly from refiners, and borrow from multiple sources, condition (2) ensures that in the case where the number of unconstrained (resp constrained) traders approaches zero, there is an equilibrium approaching one described in the previous section, where traders only purchase on credit from the DOTs.

2 Estimates of the Effects of the Policy Reform from the Before-After Approach

In this subsection of the online appendix, we report the estimates from the before-after (BA) approach and discuss the sources of bias in these estimates. Recall that our main interest is the direction of *change* in the pass-through rate, i.e., the sign of θ_3 in equation (35) in the main text. Denoting the coefficient on oil import price in a regression of C_t on P_{tm} by ρ_s in regime $s = 0, 1$, the estimated pass-through rate is $\hat{\beta}_s = \beta_s(1 + \rho_s)$. Recall that $s = 0$ denotes the pre-reform regime, and $s = 1$ refers to the post-reform regime. If the correlation between C_t and P_{tm} did not change as a result of the reform, i.e., $\rho_1 = \rho_0$, we can infer the direction of change in pass-through rate from a before after comparison. More generally, if $\rho_1 \geq \rho_0$ and $\rho_1 \geq 0$, we have $\hat{\beta}_1 < \hat{\beta}_0$ only if $\beta_1 < \beta_0$. Hence under this assumption we would be able to still reject the standard model despite the lack of cost data, if the estimated pass-through rate falls after the reform.

Data on diesel prices provide evidence in favor of the assumption that $\rho_1 \geq \rho_0$ and $\rho_1 \geq 0$. The correlation between diesel price and crude oil import price was virtually zero in pre-reform period as government controls decoupled the domestic diesel price from the fluctuations in international prices. During the post-reform period, the correlation was 0.45 as international

oil prices eased, whence the government allowed more flexibility in price setting at gas stations.

A limitation of this approach is that the correlation of the oil import price with other sources of domestic processing and distribution costs cannot be assessed and thus the direction of omitted variables bias remains unknown. Moreover, it does not permit any inferences concerning changes in the intercept term, which is relevant to assessing the impact of the reform on the level of downstream prices. The bias in the BA estimate of the intercept term in regime s equals $\beta_s {C^0}_s$ where ${C^0}_s = \left(\bar{C}_s - \rho_s \bar{P}_{ms}\right)$ denotes the intercept term in the regression of distribution costs C_t on the crude oil import price P_{tm} in regime s. Inferring the direction of change in the intercept term is therefore not possible, without making assumptions regarding the before-after difference in average distribution costs.

An alternative way of dealing with the bias in the BA estimates is to control for variables that proxy for refining and distribution costs, such as the diesel price and exchange rate. Most of the trucks run on diesel and the privately owned electricity generators also use diesel. Electricity outage and load shedding were common in Bangladesh during the study period. Since almost all transport equipment are imported into Bangladesh, exchange rate changes can directly affect a major component of costs in the transport sector.

Appendix Table T.1 reports the estimates from the BA approach: the first two columns contain the estimates for wholesale price and the last two the estimates for retail (consumer) prices. The estimates consistently show that the reform increased the intercept and reduced the passthrough rate, and these conclusions are valid for both the wholesale and retail (consumer) prices.

Online Appendix Tables (Not for Publication)

Table T.1: Before-After Analysis
Dependent Variable: Wholesale price of Palm oil

	Estimated Effects before-after analysis (1-year pre-reform and high price sample)			
	Wholesale Price		Retail Price	
	(1)	(2)	(3)	(4)
Reform Dummy	29.87	31.73	23.66	24.77
	(13.47)	(12.56)	(10.22)	(9.465)
Reform Dummy * Palm World Price	**-0.279**	**-0.256**	**-0.221**	**-0.204**
	(0.159)	**(0.148)**	**(0.123)**	**(0.115)**
Palm World Price	0.812	0.730	0.732	0.676
	(0.0892)	(0.101)	(0.0648)	(0.0719)
Intercept	20.32	98.02	32.44	83.44
	(8.025)	(25.65)	(5.791)	(18.05)
Observations	426	426	426	426
Year and Quarter dummies	Yes	Yes	Yes	Yes
Ramadan Dummies	Yes	Yes	Yes	Yes
Proxies for Distribution Costs	No	Yes	No	Yes

Notes: (a) The reform dummy=1 if an observation is from after the date of the actual reform: June 21, 2011. (b) The sample consists of the period from June 3, 2010 to October 4, 2012, but the announcement phase (90 days) is excluded. Observations for palm, wheat and lentil: Pre-reform: 175; Post reform: 251. (c) Unit for Palm is Litre. (d) Proxies for distribution costs include diesel price and exchange rate. (e) Standard errors are in parentheses and are corrected using Newey-West (1987) procedure for heteroskedasticity and autocorrelation, assuming AR (3) process. (f) Augmented Dickey-Fuller and Panel Unit Root Tests Reject the Null Hypothesis of Unit Roots in the Residuals.

Table T.2: DiD Estimates Allowing for Different Passthroughs for Wheat and Lentil
Dependent Variable: Wholesale price of Palm oil

VARIABLES	1-year pre-reform sample			2-year High price
	Main Sample	**Incl Announce.**	**Incl. low price**	**Sample**
	(1)	(2)	(3)	(4)
Policy Reform Dummy	-1.263	-3.669	-0.866	1.702
	(1.568)	(1.097)	(1.536)	(1.464)
Reform Dummy*Palm Dummy	**49.71**	**50.94**	**37.17**	**72.29**
	(7.318)	**(7.186)**	**(6.734)**	**(7.292)**
Reform Dummy*Palm Dummy*World Price	**-0.546**	**-0.561**	**-0.369**	**-0.817**
	(0.0995)	**(0.0968)**	**(0.0906)**	**(0.100)**
Reform Dummy*World Price	0.0252	0.0332	-0.0233	-0.00122
	(0.0173)	(0.0155)	(0.0166)	(0.0223)
World Price*Palm Dummy	0.493	0.628	0.341	0.580
	(0.152)	(0.155)	(0.138)	(0.143)
World Price	0.293	0.155	0.404	0.488
	(0.150)	(0.153)	(0.142)	(0.140)
Palm dummy	5.182	2.843	10.90	-13.14
	(3.877)	(3.921)	(3.242)	(4.023)
Lentil Dummy	38.33	36.82	36.14	32.13
	(5.504)	(5.247)	(5.830)	(6.471)
Lentil Dummy*World Price	-0.128	-0.00639	-0.148	-0.127
	(0.180)	(0.178)	(0.182)	(0.182)
Intercept	95.69	81.70	66.20	102.9
	(17.32)	(15.96)	(20.22)	(16.83)
Observations	1,090	1,252	1,252	1,391
Year and Quarter dummies	Yes	Yes	Yes	Yes
Ramadan Dummies	Yes	Yes	Yes	Yes
Proxies for Distribution Costs	Yes	Yes	Yes	Yes

Notes: (a) The reform dummy=1 if an observation is from after the date of the actual reform: June 21, 2011. (b) The sample consists of the period from June 3, 2010 to October 4, 2012, but the announcement phase (90 days) is excluded. Observations for palm, wheat and lentil: Pre-reform: 399; Post reform: 691. (c) Unit for Palm is Litre and for Wheat and Lentil Kg. (d) Proxies for distribution costs include diesel price and exchange rate. (e) Standard errors are in Parenthesis and are corrected using Newey-West (1987) procedure for heteroskedasticity and autocorrelation, assuming AR (3) process. (f) Augmented Dickey-Fuller and Panel Unit Root Tests Reject the Null Hypothesis of Unit Roots in the Residuals.

Table T.3: Robustness checks: DiD Estimates
Dependent Variable: Wholesale price of Palm oil

	Restricted Sample	Month*Year Fes
	(1)	(2)
Policy Reform Dummy	-1.161	-8.683
	(1.555)	(2.994)
Policy Reform*Palm dummy	**46.59**	**52.77**
	(8.238)	**(7.389)**
Policy Reform*Palm*World Price	**-0.513**	**-0.590**
	(0.110)	**(0.0997)**
Policy Reform*World Price	0.0390	0.0435
	(0.0180)	(0.0192)
World price*palm	0.525	0.423
	(0.101)	(0.0953)
World price	0.185	0.327
	(0.0665)	(0.0746)
Palm dummy	8.974	8.694
	(5.599)	(3.477)
Lentil Dummy	34.87	30.09
	(2.543)	(2.834)
Intercept	86.35	23.77
	(15.39)	(20.50)
Observations	991	1,090
Year and Quarter dummies	Yes	No
Year*Month Dummies	No	Yes
Ramadan Dummies	Yes	Yes
Proxies for Distribution Costs	Yes	Yes

Notes: (a) The reform dummy=1 if an observation is from after the date of the actual reform: June 21, 2011. (b) The sample consists of the period from June 3, 2010 to October 4, 2012, but the announcement phase (90 days) is excluded. Observations for palm, wheat and lentil: Pre-reform: 399; Post reform: 691. (c) Unit for Palm is Litre and for Wheat and Lentil Kg. (d) Proxies for distribution costs include diesel price and exchange rate. (e) Standard errors are in Parenthesis and are corrected using Newey-West (1987) procedure for heteroskedasticity and autocorrelation, assuming AR (3) process. (f) Augmented Dickey-Fuller and Panel Unit Root Tests Reject the Null Hypothesis of Unit Roots in the Residuals.

Table T.4: Summary Statistics over entire estimation period (includes both pre- and post-reform periods

	Samples consist of post-reform plus			
	1-year Pre-reform		2-Year Pre-reform	
	Mean	**SD**	**Mean**	**SD**
Palm				
Wholesale price	85.98	10.59	78.71	15.06
Retail price	90.32	11.14	82.71	15.77
World Price (4 weeks lagged)	73	11.47	66.64	14.51
World Price (Current)	74.76	11.46	67.99	15
Wheat				
Wholesale price	23.91	2.05	23.91	2.05
Retail price	26.5	2.34	26.5	2.34
World Price (4 weeks lagged)	18.6	1.54	18.6	1.54
World Price (Current)	18.82	2.5	18.82	2.5
Lentil				
Wholesale price	66.74	4.53	70.24	7.73
Retail price	74.2	3.95	77.29	6.99
World Price (4 weeks lagged)	56.32	4.45	58.36	5.57
World Price (Current)	56.34	5.37	58.26	6.16

Notes: (a) SD stands for Standard Deviation. (b) The "1-year pre-reform" Includes 1 year before the announcement date of reform, "2-year pre-reform sample" spans 2 years before the announcement date of reform. The announcement period (90 days) is excluded from both samples. The 1-year pre-reform sample covers June 3, 2010 to October 4, 2012, and the 2-year pre-reform sample covers from May 31, 2009 to October 4, 2012. There are gaps in data due to weekends and festivities. (c) Unit for Palm is Litre, and for Wheat and Lentil Kg. (d) All prices are in the local currency, Taka.

Table T.5: Summary Statistics during pre-reform and post-reform periods

	1-year Pre-reform		2-Year Pre-reform		Post-Reform	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Palm						
Wholesale price	76.96	10.56	68.48	11.93	92.27	4.05
Retail price	80.11	10.58	71.61	11.92	97.43	3.07
World Price (4 weeks lagged)	65.22	13.31	57.75	12.81	78.42	5.32
World Price (Current)	69.12	14.18	59.92	14.46	78.7	6.74
Wheat						
Wholesale price	25.42	1	25.42	1	23.32	2.05
Retail price	27.86	0.95	27.86	0.95	25.97	2.5
World Price (4 weeks lagged)	18.84	1.26	18.84	1.26	18.5	1.63
World Price (Current)	18.74	1.46	18.74	1.46	18.85	2.81
Lentil						
Wholesale price	68.67	1.85	74.25	7.29	65.58	5.21
Retail price	76.06	1.1	81.02	6.68	73.13	4.57
World Price (4 weeks lagged)	59.27	4.45	61.72	4.92	54.6	3.44
World Price (Current)	59.71	5.81	61.8	5.66	54.35	3.92

Notes: (a) SD stands for Standard Deviation. (b) The "1-year pre-reform" Includes 1 year before the announcement date of reform, "2-year pre-reform sample" spans 2 years before the announcement date of reform. The announcement period (90 days) is excluded from both samples. The 1-year pre-reform sample covers June 3, 2010 to October 4, 2012, and the 2-year pre-reform sample covers from May 31, 2009 to October 4, 2012. There are gaps in data due to weekends and festivities. (c) Unit for Palm is Litre, and for Wheat and Lentil Kg. (d) All prices are in the local currency, Taka.

Figure F.1: Palm World Price:Pre-reform period

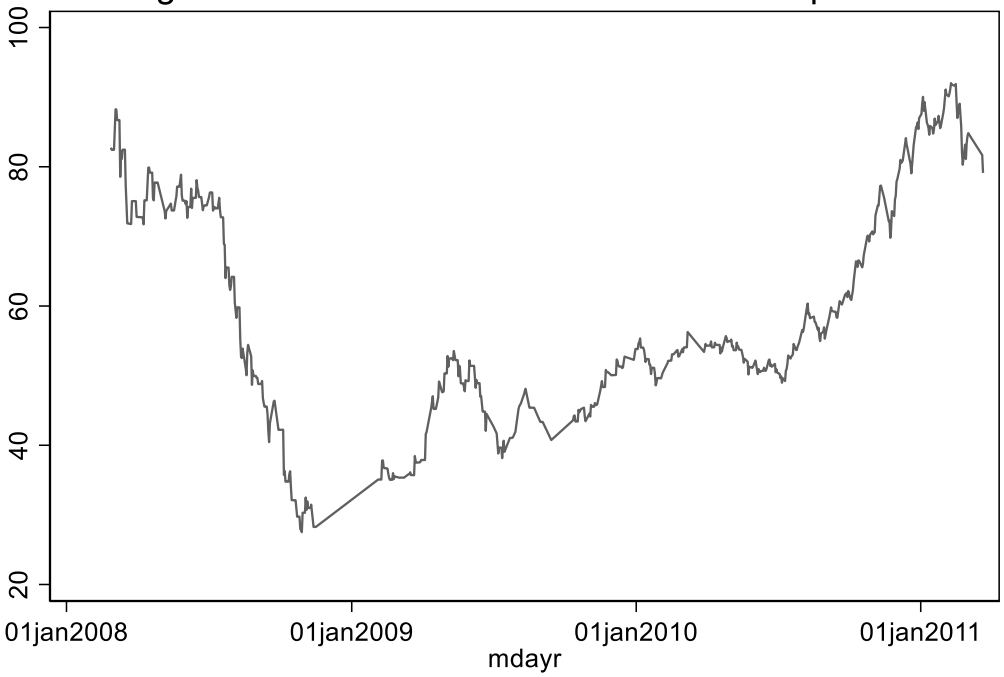
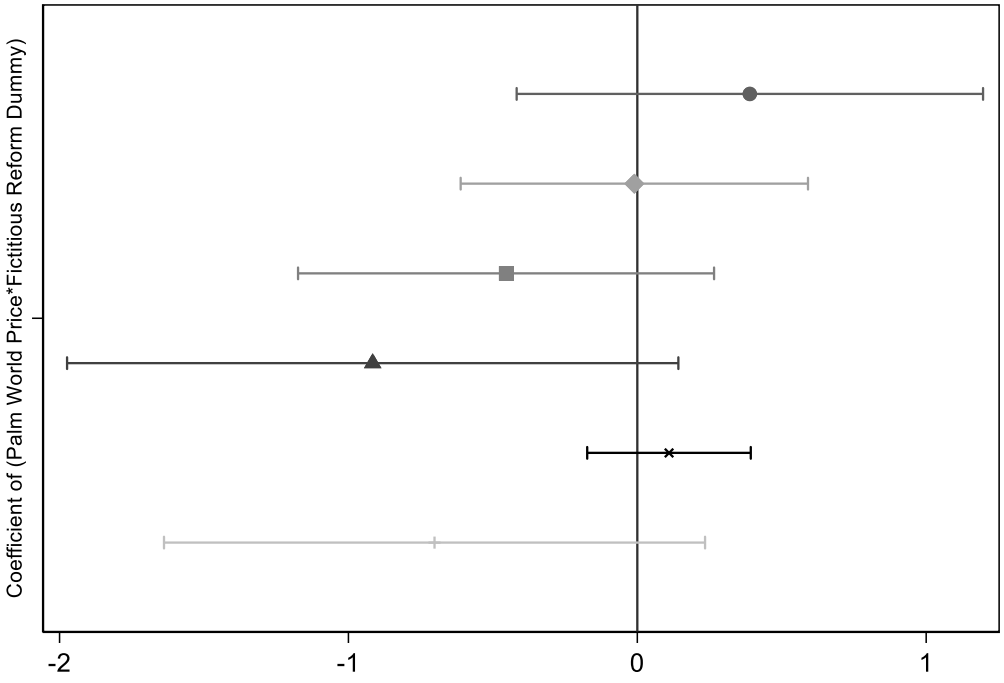


Figure F.2: Palm Price Pass Through rel. to Lentil and Wheat during Pre-Reform



Notes: (1) The point estimates of the effects of placebo reform on the passthrough of international prices of crude palm oil to wholesale prices along with 95% confidence intervals are reported. (2) The sample used is the main sample that covers 1 year before the announcement of the reform. The fictious policy reform for the first bar is when reform is assumed to cover between June 3, 2010 to July 14, 2010 (one-sixth of the pre-reform sample) and so on.

Figure F.3: Impact of Reform on Pass-through

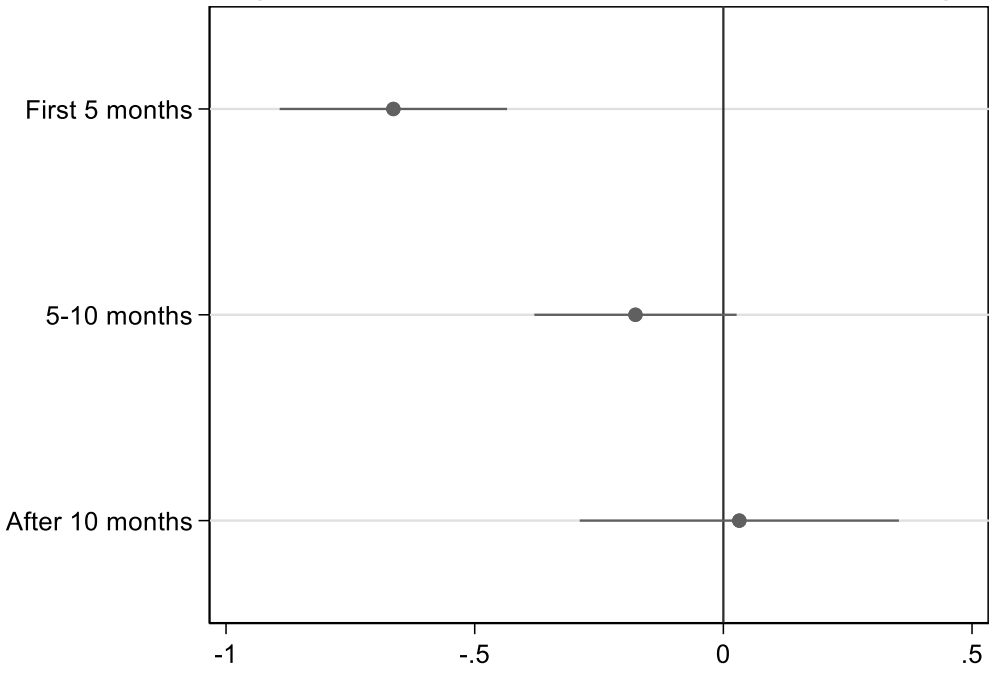


Figure F.4: Impact of Reform on Intercept